Development and application of food by-product extracts based edible coating on fruits

A thesis submitted in partial fulfillment of the requirement for the award of degree of

MASTER OF SCIENCE

IN

BIOTECHNOLOGY

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Submitted by

Navdeep Kaur

(302301009)

Under the guidance of

Dr. Oves Shafiq Qadri (Assistant Professor)

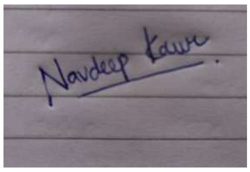
Department of Biotechnology

TIET, Patiala

July 2025

DECLARATION

I hereby declare that the work presented in the thesis **“Development and application of food byproduct extracts based edible coating of fruits”** in the partial fulfillment of the requirement of the award of the degree of Master of Science in Biotechnology at Thapar Institute of Engineering and Technology (TIET), is an original and genuine work completed by me between January 2024 and July 2024. This research was carried out under the guidance and supervision of Dr. Ovais Safiq Qadri, an Assistant Professor in the Department of Biotechnology, TIET. The content presented in this thesis has not been previously submitted, either in its entirety or in part, to any other educational institution or university in India or abroad for the purpose of obtaining any degree. Whenever references have been made to the previous works of others, they have been clearly indicated as such and included in the Bibliography.



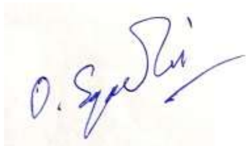
Place – Patiala

Navdeep Kaur

Date - 08-09-2025

CERTIFICATE

This is to certify that the thesis entitled **"Development and application of food by-product extracts based edible coating on fruits**" Submitted by Ms. Navdeep Kaur (302301009) in the partial fulfillment of the requirement of the award of the degree of Master of Science in Biotechnology at Thapar Institute of Engineering and Technology (TIET) Patiala, (Deemed to be University) is a record of student's own work carried out under my supervision and guidance. This work has not been submitted in part or full to any other university or institute for the award of any other degree.



Date: 08-09-2025

Supervisor

Dr. Ovais S. Qadri
Assistant Professor
Department of Biotechnology
TIET, Patiala

ACKNOWLEDGEMENT

First and foremost, I would like to thank God for showering his blessing, which inspired and enabled me to complete my dissertation. I consider myself incredibly fortunate to have received support from various sources, including the department, my family, friends, and colleagues. Without their support, it would not have been possible for me to complete my thesis successfully.

I would like to show my gratitude to my honorable and respectful supervisor, **Dr. Ovais Shafiq Qadri**, Assistant Professor, Department of Biotechnology at Thapar Institute of Engineering and Technology, Patiala, for giving me the opportunity to work under his guidance. His continuous efforts, monitoring of my work, and guidance helped me complete my research work. Without his insistent help and guidance, I would have never been able to complete the report. Apart from research, I learned a lot from him and feel blessed to work under his supervision.

I am also thankful to the Department of Biotechnology and STEP for providing me with the necessary infrastructure and resources for my work. I am also grateful to Dr. Samandeep Kaur, Research Assistant Professor at the Department of Biotechnology for her constant cooperation, sympathy, encouragement, suggestion, keen personal interest, and scholarly criticism.

I owe my deepest gratitude to Ms. Navdeep Kaur (PhD scholar) for her constant support during my dissertation. I am truly grateful for her willingness to dedicate time and effort to address my queries, provide feedback, and offer valuable suggestions. Her presence and responsiveness have been instrumental in ensuring the smooth progress of my thesis work.

I would like to thank my lab partners, Ms. Deepanshi Sharma and Ms. Alshifa Sheikh, for their positive support during my experiments and for helping me to adjust in the lab environment. Their positivity and camaraderie have been greatly appreciated. I would like to acknowledge and thank all those who assisted me during these memorable six months. Thank you all for your constant encouragement.

TABLE OF CONTENT

LIST OF SYMBOLS

Acronym	**Definition**
°C	Degree Celsius
%	Percentage
g	gram

LIST OF ABBREVIATION

Abbreviation	**Full form**
pH	Potential of Hydrogen
TSS	Total Soluble Solids
TA	Titratable Acidity

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The postharvest losses of papaya fruits are important concerns during storage, shipping and marketing. These losses might happen because of things like microbial infection, temperature, improper handling, and other factors. Using edible coatings that are made from food by-product extracts and last longer will help lower this. This study was carried out to determine the effect of a moringa seed oil–starch coating on the quality of post -harvested papaya at different storage temperatures for 15 days of storage. Post- harvested papayas purchased from market were divided into two groups: the first group was coated with the moringa seed oil–starch edible coating, while the other one was not coated (control). Each group was divided into three other subgroups, for storage at 4, 10, and 25°C. Different quality parameters, including weight loss, color change, total soluble solid (TSS), total carotenoid content, titratable acidity (TA), TSS: TA, pH and microbial analysis were evaluated. The lower the temperature, the more papaya was preserved for 15 days, with increase in temperature the loss in evaluated parameters was observed. But the loss for non-coated (control) was more as compared to the coated samples. Moringa seed oil-starch edible coating has the potential to preserve the nutritional value and quality attributes of post-harvested papayas. This edible coating was considered eco-friendly; it helps to reduce food by-product extract waste.

Chapter – 1

Introduction

Fruits are important to eat as they are good for health and provide important nutrients. But they do not last very long after harvest they are likely to spoil due to changes in environment. The changes in the fruits physiology, which occurs because of physical or pathological causes resulting in significant economic losses. The changes in fruits appearance reduces its market value. When fruits and vegetables are handled and stored after they are picked, they lose weight through transpiration. This changes their texture and makes their surfaces shrink, which shortens their shelf life. On the other hand, the breakdown of cell wall components, especially pectin, by different enzymes is also thought to be what makes fruit mushy as it is being stored (Sapper & Chiralt, 2018).

Edible coatings are thin layers of digestible materials applied to food products. These coating are composite- made from two or more polymers. The polymers can be lipids, carbohydrates and proteins or synthetic and natural polymers. The combinations of polymers should be beneficial for different functional characteristics (Adjouman et al., 2018). Edible coatings provide protective covering for fruits to increase their shelf life. These coatings act as modified atmosphere for fruits as it can modify the internal gas composition. Mostly the quantity and quality losses occur between harvest and consumption period known as post-harvested losses. Wax was the first edible coating that was used. Around 12th and 13th century, wax was used as edible coating for oranges and lemons by Chinese. In 1930, hot melted paraffin waxes were commercially available for coating apples and pears. Then, it was reported that these coating decreases water vapor and oxygen transmission which increases the shelf life of fruits (Park, n.d.). Water loss has great impact on post harvested fruits which is major cause of deterioration. These water losses lead to quality changes color changes, texture, nutritional losses and physiological behavior (Nunes & Emond, 2007).

According to (Thakur et al.,2017) the effectiveness of fruit coating materials mostly depends on what the coating ingredients are and how much of each one is needed. The food by-products extracts were considered much efficient for making edible coatings as such coatings were considered more safer for human consumption. Using such edible coatings offers the benefit of decreasing packaging waste, prolonging the shelf life of fresh and minimally processed food, and protecting it from harmful environmental effects by making sure that oxygen, carbon dioxide, moisture, fragrance, and taste chemicals are moved into and out of the food system. Edible coatings prepared by using food by-product extracts are used because they are cheap, eco-friendly and keep fruits fresh for longer while it is being stored (Al-Rashdi et al., 2024). Natural antimicrobial coatings made from food by-product extracts were proven to be excellent alternative for extending shelf life of fruits. The deterioration of fruits not only lead to economic losses but also contribute to food waste and scarcity. So, the edible coatings are alternative sustainable method with increasing demand of natural, safe and eco-friendly food preservative techniques (Sharma et al., 2024). Starch is present in the plant derivative product. It is a good barrier for water and oxygen but it has only modest mechanical qualities that can be improved by mixing it with other food components. Another option for keeping food fresh is lipid-based edible coatings or films. These chemicals might come from plants or animals. Lipids are lipophilic, which means they can hold a lot of moisture. Essential oils are also a type of lipid that is used to make edible coatings and films for preserving processed foods (Antonino et al., 2024).

The edible coating can be applied on fruits in different ways. The dipping method is one way to apply edible coatings. In this procedure, the food is dipped right into the coating solution. When the product dries naturally, a thin layer of coating appears on its surface. The spraying approach is another way to apply solutions with low viscosity at low pressure. The spreading method, on the other hand, involves directly brushing the coating solution onto the fruit. After applying coating on fruits with any one of method, then the coating is dried by tampering process (Antonino et al., 2024).

This study aims to use the food by-product extracts for developing an edible coating for tropical fruit, Papaya. The food by-products used were the seeds of *Moringa oleifera* plant from which oil was extracted and the seeds of *Syzygium cumini* from which starch was extracted and an emulsion was prepared by using soy lecithin as an emulsifying agent in it. An oil-in-water emulsion was made which results as an edible coating for extending the shelf life of papaya (Adjouman et al., 2018).

Chapter – 2

Review of Literature

2.1 Papaya

Papaya is one of the most grown fruits in subtropical and tropical regions of world, majorly in tropical areas. Brazil is the second largest producer and exporter of papaya. Papaya is popular and demanded in market because of its nutritional components such as fiber, vitamin and minerals (do Nascimento et al., 2023). Papaya is more nutritious and have longer season then other fruits. Ripened papaya has 32 calories, 0.6 g protein, 0.1 g fat, 7.2 g of carbohydrates and 2.6 g of fiber per 100 g (Raju et al., 2023). Papaya is characterized by the increase in the respiratory rate, an autocatalytic production of ethylene and sensory alternations such as color, flavor and softening during ripening (Castricini et al., 2012). In addition, papaya is also source of a digestive enzyme papain, which is used as an industrial ingredient in brewing, tenderizing meat, in pharmaceuticals, beauty products and cosmetics. The major problem faced in papaya production is the post harvested losses due to some factors such as fungal disease, physiological disorders and the damage caused during transportation (Evans & Ballen, n.d.). Due to the ethylene production the papaya ripens very rapidly at room temperature. As it ripens it feels softer and color changes to red–yellow. The shelf life of ripened papaya is 2 to 3 days. The two flesh colors of papaya are controlled by the same gene, however the yellow color is always dominant. The red color visible in papaya is because of accumulation of lycopene, whereas yellow color is the conversion of lycopene to beta-carotene and beta-cryptoxanthin. As the fruit ripens, its color changes. The flesh color of papaya is considered a quality trait that correlates with the nutritional value of papaya and shelf life of fruit (Essa et al., 2012).

2.2 Taxonomy of Papaya

Kingdom - Papaya

Division – Magnoliophyte

Class – Magnoliopsida

Order – Brassicales

Family – Caricacea

Genus – Carica

Species – Papaya

2.3 Nutritional value of papaya

Papaya is considered as nutrient dense fruit as compared to other fruits as it provides more nutrients on per calorie. The chemical composition, vitamin and mineral composition of papaya is given in table 2.1 and 2.2. It has negligible amount of cholesterol and fat. The carbohydrate source in papaya is present in the form of invert sugars which are easily digestible and adsorbed. Papaya is excellent source of fibers which help to reduce high blood cholesterol level and constipation. The vitamin A and vitamin C are present in large quantity in papaya. The Vitamin K, vitamin E, niacin, thiamine, riboflavin, pyridoxine and folate are present in small quantities. Homocysteine is converted to cysteine and methionine with the help of folic acid which helps to reduce the changes of heart failure or stroke. It also contains some amount of calcium, magnesium, potassium, iron, manganese, zinc, copper, boron and selenium. Low levels of sodium and high level of potassium help hypertensive people to balance their intake of sodium (Essa et al., 2012).

Table 2.1 The vitamins and mineral composition of fresh papaya fruit (Essa et al., 2012)

PARAMETER	RANGE
Vitamin A (RAE)*	23 – 55 (μg/100g)
Vitamin E	3.13 – 5.3 (mg/100g)
Vitamin K	2.3 – 2.9 (μg/100g)
Vitamin C	57 – 108 (mg/100g)
Thiamine (vitamin B1)	0.04 – 0.05 (mg/100g)
Riboflavin (vitamin B2)	0.05 - 0.07 (mg/100g)
Niacin	0.34 – 44 (mg/100g)
Pyridoxine	0.1 – 0.15 (mg/100g)
Folate	39 – 55 (μg/100g)
Calcium	17 – 24 (mg/100g)
Phosphorous	5 – 9 (mg/100g)
Magnesium	10 – 33 (mg/100g)
Sodium	3 – 24 (mg/100g)
Potassium	90 – 257 (mg/100g)
Iron	0.23 - 0.66 (mg/100g)
Manganese	0.01 – 0.03 (mg/100g)
Zinc	0.06 – 0.09 (mg/100g)
Copper	0.06 – 0.14 (mg/100g)
Boron	0.01 – 0.21 (mg/100g)
Selenium	1.2 – 1.5 (μg/100g)

Table 2.2 Chemical composition of fresh papaya fruit (Essa et al., 2012)

PARAMETER	RANGE
Energy	39.0 - 41.4 (kcal/100g)
Moisture	86.9 – 89.8 %
Crude protein	0.5 - 0.6 (g/100g)
Total fat	0.1 - 0.14 (g/100g)
Ash	0.5 - 0.7 (g/100g)
Crude fibre	0.4 - 0.8 (g/100g)
Dietary fibre	0.5 - 2.2 (g/100g)
Carbohydrates	7.5 - 10.98 (g/100g)
Total Sugars	7.2 - 9.8 (g/100g)
Sucrose	1.9 - 6.1 (g/100g)
Glucose	2.6 -3.4 (g/100g)
Fructose	2.1 - 2.6 (g/100g)

2.4 Review on study of different edible coatings for different fruits

Numerous studies have been conducted on edible coating of different fruits. With focus on different methods, techniques, challenges and development in the field, this study attempts to examine the existing literature in preparation of edible coating on different types of fruits which helps to increase the shelf life of post harvested fruits. This study aims to provide insights of using different ingredients for making edible coating of fruits, how these coatings are beneficial for post harvested fruits and is not harmful for human consumption. The ingredients used for developing edible coating are extracted from food by-product extracts.

Nano Chitosan Avocado seed starch edible coating for strawberries

Chitosan is a bioplastic, so a biodegradable film was made from mixture of nano chitosan and avocado seed starch. Avocado seed has 43.3% of starch, which is the one of agricultural waste produced by Indonesia. Casting method was used for making film and characterization was performed which includes functional group, thickness, color and antioxidant test. The thickness of film was 0.10- 0.15 with darker color. This coating film was synthesized by sonication method and was used on strawberries which helped to keep strawberries fresh for 72 hours (3 days). Strawberries not packed with film were characterized with shrinkage of fruit volume, decrease in freshness and appearance of mold on the surface of fruit (Solihat et al., 2023).

Mung bean starch as an edible coating for papaya

It is an innovative edible coating for increasing shelf life of fresh cut papaya. The mung bean starch edible coating had helped to reduce the loss of total soluble solids and maintenance of acidity levels. The freshness and quality of the papaya was retained for 12 days because of barriers created by starch against the moisture loss, gas exchange and oxidation. Mung bean starch contains antimicrobial compounds such as flavonoids, phenolic acids and saponins. Considering these benefits of starch, as edible coating, has created interest of researchers related to different types of starch that can be used in edible in coating at different concentrations (Sharma et al., 2024).

Cassava starch edible coating on post – harvest quality of fresh tomatoes

Tomato is a climacteric fruit that ripens after harvested. The post-harvest ripening process can lead to quality degradation and reduced shelf life. The preparation of edible coating was done using 4% starch, 25% glycerol, 5% essential oil and 5% soy lecithin. Soy lecithin was used as an emulsifying agent for making coating emulsion. The prepared coating was applied to tomatoes and were stored at 22°C. Cassava starch based edible coating helped to preserve the tomatoes for about a month while maintaining temperature and relative humidity. This study indicates the reduced weight loss coated tomatoes than uncoated ones, the color maintenance, drop in acidity, increase in total soluble solids and pH (Adjouman et al., 2018).

Sweet potato starch incorporated with essential oil for pears

The sweet potato starch was used along with essential oil for making edible coating to maintain storage quality of 'early crisp'. This study helps to make an antifungal coating with starch at 0.2% and 0.4% concentrations. This coating also helped to reduce water loss, firmness deterioration, color changes and spoilage by caused by *Alternaria alternata.* This study depicted about the preservation of stomatal densities and internal quality of 'early crisp'. The stomatal densities are preserved by modifications in the internal atmosphere of fruit by the composite formulation against moisture loss (Oyom et al., 2022).

Starch edible coating of papaya

Cassava starch (CS) coating was prepared with different concentrations 1%, 3% and 5% and carboxymethyl starch (CMS). The formulation was made by stirring starch into distilled water at 70° C and after this was kept at room temperature for cool down. The cassava starch and carboxymethyl starch (CMS) coating has the taste characteristics. Coatings with 3% and 5% preserved their green color. The 5% coating of cassava starch was better for the papaya than the CMS and 1% and 3% CS concentrations for most of the qualities considered (Castricini et al., 2012b).

Cassava starch coating with cinnamon essential oil for papaya

Cassava starch with cinnamon essential oil along with 2% and 3% concentration of sodium alginate (v/w) was used for coating preparation which was applied on papaya stored for 12 days at 25°C. This coating was considered efficient for increasing the shelf life of papaya with reduction in weight loss and this coating has improved the microbiological parameters. It helps to reduce aerobic mesophiles, yeasts and molds due to antimicrobial effect of essential oil. 4% cassava starch with essential oil was considered best concentration for microbiological control which is very important for maintaining post -harvested shelf life of papaya (do Nascimento et al., 2023).

Lecithin Isolate from vegetable oil as an emulsifier on the beeswax coating

Lecithin was isolated from vegetables oil. Rice bran mixed with soy lecithin in 1:6, the mixture was analyzed as an emulsifier by determining its Hydrophilic-lipophilic balance (HLB). The mixture was used with beeswax in different concentrations 0%, 0.25%, 0.5%, 0.75% and 1% (v/v). the creamy index of formulations was determined by mixing 10% plant-based oil with water adding 1% plant- based lecithin. Then creamy index was determined for the prepared coating. Beeswax coating characteristics were significantly influenced by varying concentrations (%) of plant-based lecithin, including 0, 0.25, 0.5, 0.75, and 1. The pH values increased as the concentration of lecithin increased (Hakim et al., 2020)

Moringa Seed Oil, Algae Extract and Arabic Gum Postharvest Treatments on Hass Avocado

The coating was prepared with three ingredients in different amounts ; Algae extract at 1000 ppm+5% Arabic gum, Algae extract at 1000 ppm+10 % Arabic gum, *Moringa peregrina* oil at 1000 ppm+ 5% Arabic gum, *Moringa peregrina* oil at 1000 ppm +10% Arabic gum, *Moringa stenopetala* oil at 1000 ppm +5% Arabic gum, *Moringa stenopetala* oil at 1000 ppm +10% Arabic gum, *Moringa oleifera* oil at 1000 ppm +5% Arabic gum and *Moringa oleifera* oil at 1000 ppm +10% Arabic gum. These coatings were applied on avocado and were stored for 45 days. All of the treatments in the study had an effect on cold storage at 5±1°C and 85–90% RH compared to the untreated fruits. The best treatment was Moringa oleifera seed oil at 1000 ppm plus 10% Arabic gum. It made the avocado fruits firmer, more acidic, and more active in polyphenol oxidase (PPO) during the storage period. The untreated avocado fruits (control) lost firmness, TSS, ascorbic acid, total phenol, and carotenoids levels slowly go down when they were stored in the cold at 5±1˚C and 85–90% RH (El-Moniem et al., 2023).

Moringa Oil–Beeswax Edible Coating on the Shelf-Life and Quality of Fresh Cucumber

The purpose of this study was to see how a moringa oil-beeswax coating affected the quality of fresh cucumbers after 27 days of storage at varied temperatures. The coating was formulated by heating 80ml of Moringa oil and 20g of beeswax in an oven at 120°C. The freshly selected cucumbers were divided into two groups. The first group was coated with the edible coating made of moringa oil and beeswax, and the other was the control. There were three more subgroups for each group for storage at 4, 10, and 22 °C. The results showed that this coating preserved the nutrients such as vitamin C, slowed pH reduction, maintained color intensity and reduced the weight loss. The lower temperature (4°C) showed more positive results. Color changes were better maintained at temperature more than 13°C. Moringa oil-beeswax coating was considered more safe, effectively bridgeable and eco-friendly which helped to replace the preservatives and packaging materials used to increase shelf life of cucumber. This study confirmed the use of such natural ingredients for making edible coating for other fruits and vegetables (Al-Rashdi et al., 2024).

Moringa Gum and Cinnamon Essential Oil as Edible Herbal Coating for Extending Shelf Life and Quality of Guava

Guava is a climactic fruit it ripens after harvested. It is a pleasant and rich in vitamin C, to protect it from post harvested losses moringa gum (concentration from 1% to 5%) and cinnamon essential oil along with distilled water was mixed for making coating to increase shelf life of post harvested guava. This study concluded that moringa gum and cinnamon essential oil can preserve guava at room temperature. Herbal edible coating gave better results for weight loss, shrinkage index, total soluble solids, pH and mesophilic microbial decay. It also helped to maintained visual appearance, titrable acidity, antioxidant and phenolic content. The 3% and 4% concentration of moringa was analyzed more efficient for edible coating than the 1%, 2% and 5% concentration. The 5% showed less efficient due to high concentration and 1-2% has shown less effect because of low concentration (Hasan et al., 2022).

2.5 Gap in literature

Moringa seed oil, extracted from seeds of *Moringa oleifera* plant was used for making edible coating along with starch extracted from jamun seeds and soy lecithin as an emulsifying agent. The present study focuses on the use of *Moringa oleifera* seed oil for preparing edible coating along with starch, that has not been used before. The importance of present study is:

- Limited research has been done on edible coating of fruits using *Moringa oleifera* seed oil.
- The use of edible coating developed from *Moringa oleifera* seed oil mixed with starch extracted from *Syzgium cumini* seeds in which soy lecithin was used as emulsifying agent for the preparation of oil-in-water emulsion which has not been done on tropical fruits in past studies.

2.6 Objective of study

- Development of composite edible coating using *Moringa oleifera* seed oil.
- Application of developed coating on papaya.
- To study the effect on shelf life and quality analysis.
- To study effectiveness of coating on papaya at three different temperatures.

Chapter -3

Materials and Methods

3.1 Materials

Moringa seed oil was extracted from the seeds of the *Moringa oleifera* plant. Soya lecithin (30%) was purchased from HiMedia Laboratories Pvt. Ltd. which was used as an emulsifying agent for making oil-in-water emulsion. The starch was extracted from the seeds of jamun (*Syzygium cumini*) and Distilled water along with these three ingredients was used for making this emulsion which was used as edible coating on Papaya (*Carica papaya*).

3.2 Preparation of edible coating

The oil-in-water emulsion was prepared by using Moringa seed oil, soy lecithin, starch and distilled water based on the method used by (Adjouman et al., 2018). Initially, 5ml of Moringa seed oil was mixed with 25 ml of distilled water and 0.75 g of soy lecithin was added which was heated on a magnetic stirrer for 25 minutes at 75°C at 750 rpm. Second, 1 g of starch was mixed with 20ml of distilled water at a magnetic stirrer at 75°C for 25 minutes at 750 rpm. Then, moringa seed oil and soy lecithin solution were added into starch and the mixture was again heated at 75°C for 25 minutes at 800 rpm. The final coating was made after the mixing of these three ingredients.

3.3 Antimicrobial sensitivity test for edible coating

The antimicrobial sensitivity test was done for prepared edible coating. Nutrient agar and potato dextrose agar plates were made in which the bacterial strain *(Bacillus*) and fungus (*Aspergillus*) were streaked respectively. Next, the wells were made in both the plates in which the edible coating was loaded and plates were incubated at 37°C for 24 hours. This test was performed to check the resistance of prepared edible coating for bacteria and fungus. Then, the zone of inhibition (ZOI) was measured for edible coating and ampicillin plates. The results were observed and zone of inhibition was measured using area formulae used for circle.

$$\mathbf{Area = \pi r^2} \qquad \text{equation (1)}$$

After the area was measured of well and the zone of inhibition formed then the area of well was subtracted from the area of zone of inhibition and the final area or zone of inhibition was calculated.

3.4 Application of prepared coating on Papaya

Papaya of uniform shape, size and color without any physical damage were obtained from a local shop. Papayas were washed with water and dried under ambient air conditions before coating. Papayas were divided into 3 groups of 6 in each. Each group was stored at different temperature 4°C, 10°C and 25°C (Al-Rashdi et al., 2024). In each group the three papayas were coated with the prepared edible coating using the spraying method and the other three were kept as control. Then from each group one coated and one control sample was taken out after every 5 days interval in the storage period of 15 days for quality analysis of control and coated samples. The total eight different test were conducted for quality analysis of papaya. The results were compared between control (uncoated) and coated samples.

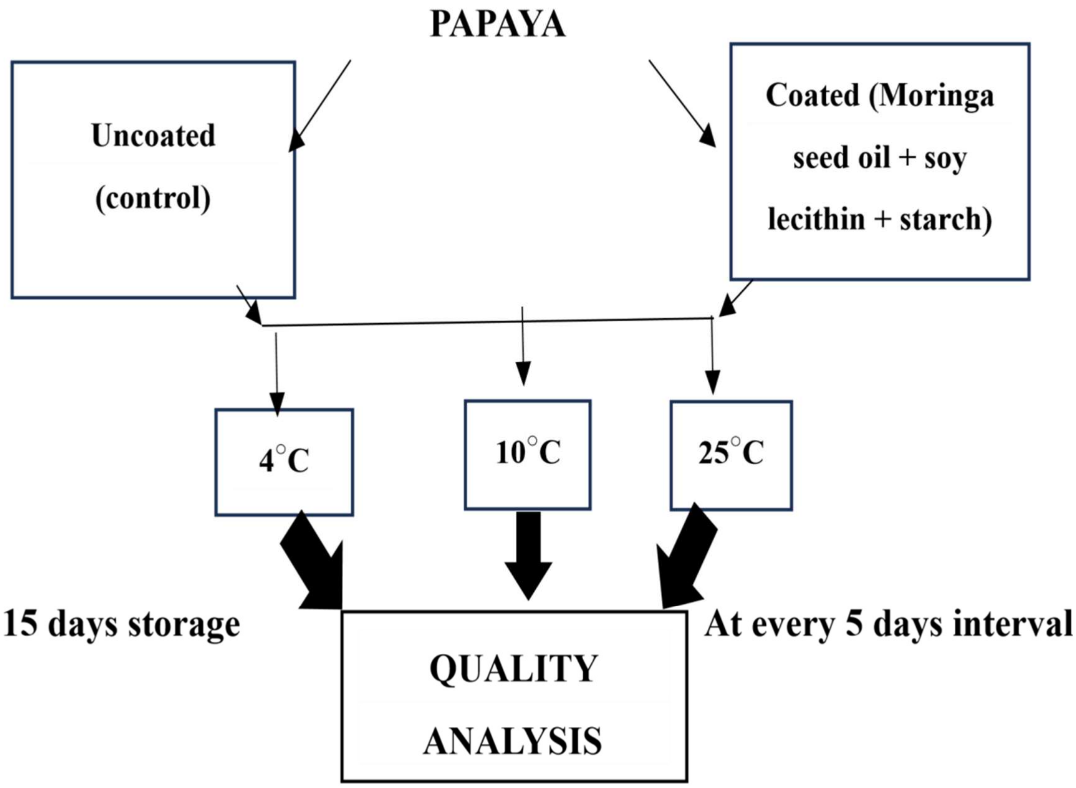


fig 1. Diagram of experiment methodology

3.5 Physio-chemical attributes

3.5.1 Weight loss percentage the weight of samples was measured using digital balance from 0 day to 15 days on every 5 days interval (Al-Rashdi et al., 2024). Before applying coating to Papaya the initial weight was recorded and the final weight of every sample was taken on 5th, 10th and 15th day of storage. The papayas were stored at 4 °C, 10°C and 25°C. Weight was recorded for control as well as coated sample. The equation (2) was used to calculate the weight loss percentage of the papayas. The equation was described by (Al-Dairi et al., 2023).

$$\textbf{Weight loss}\ \% = \frac{\mathbf{Wi - Wf}}{\mathbf{Wi}} \times \mathbf{100} \qquad \text{equation (2)}$$

W_i = initial weight of papaya

W_f = final weight of papaya

3.5.2 pH the papaya was crushed in pestle mortar and the by using muslin cloth juice was extracted. The 10ml of juice was taken in a clean beaker and the pH meter probe was inserted and it was gently stirred for few seconds (Al-Rashdi et al., 2024).

3.5.3 Titratable acidity (%) it is the volumetric method used to measure the titratable acidity. The papaya juice was extracted using pestle and mortar then filtered through muslin cloth. The 5ml of extracted papaya juice was mixed with 45ml of distilled water and the total volume was made to 50ml. Then, 10 ml of aliquot was titrated against the 0.1% NaOH, when the sample color turned to light pink the titre value was recorded (Raju et al., 2023).

$$\textbf{Titrable acidity}\ (\%) = \frac{\textbf{Titre value} \times \textbf{Normality of NaOH} \times \mathbf{67.04} \times \mathbf{100}}{\textbf{Volume of Sample} \times \textbf{Volume of aliquot} \times \mathbf{1000}} \qquad \text{equation (3)}$$

67.04 = equivalent weight for malic acid.

3.5.4 Total Soluble Solids (TSS) The papaya juice was extracted in same way as for tests done before used for measuring total soluble solids using hand refractometer and °Brix values were recorded (Athmaselvi et al., 2013).

3.5.5 Total soluble solids : Titrable acidity (TSS : TA) the TSS ratio TA was obtained by measuring the total soluble solids and titrable acidity by using equation (4). (Raju et al., 2023)

$$\mathbf{TSS : TA = \frac{TSS}{TA}} \qquad \text{equation (4)}$$

3.5.6 Water activity samples of papaya were taken and were crushed using pestle and mortar. The crushed papaya was used to measure the water activity using pawkit water activity meter made in USA. The equipment was calibrated using 0.920 standard. The three reading were recorded and the average was taken (Zamora & Chirife, 2006).

3.6 Color characteristics

The high-quality colorimeter NH300 was used for color analysis of samples. The pulp of papaya was taken from different areas and was crushed in pestle and mortar. Three readings from different parts were taken and the average value was concluded. The L*(lightness), a*(redness) and b*(Yellowness) values were recorded along with Chroma angle (C*) and hue angle (h*) for control (uncoated) and coated sample (López-Díaz et al., 2025).

$$\Delta E = \sqrt{(L^* - L^*_0)^2 + (a^* - a^*_0)^2 + (b^* - b^*_0)^2} \qquad \text{equation (5)}$$

L*, a*, b* are the color parameters for coated and control fruits.

L^*_0, a^*_0 and b^*_0 are the 0 day control values.

3.7 Total Carotenoid Test

5g of papaya was mashed in pestle and mortar and it was dipped in 20ml of acetone and placed for half an hour in the refrigerator for the extraction of carotenoid (do Nascimento et al., 2023). Then the extracts were carefully transferred to separating funnel into which 50 ml of cool petroleum ether was added for enabling the transfer of pigments from acetone to petroleum ether. In next step 60ml of distilled water was added in same separating funnel for the complete removal of acetone. In separating funnel, the layers were visible in which the lower layer was of water which was discarded and the upper layer of carotenoids was collected in amber glass bottles. Then, the absorbance was recorded in UV/vis spectrophotometer at 450nm absorbance. Finally, the total carotenoid content was calculated using the equation (6) wherein absorptivity coefficient ($E^{1\%}_{1cm}$) refers to-carotene for petroleum ether.

$$\mathbf{CT\ (\mu g \times \mathit{g}^{-1}) = \frac{Abs \times Vol \times 104}{\mathit{E}^{1\%}_{1cm} \times P}} \qquad \text{equation (6)}$$

Where CT= carotenoid content, Abs = absorbance @ 450nm, Vol = dilution volume(ml),

$E^{1\%}_{1cm}$ = 2592, P = sample weight (g)

3.8 Microbial analysis

The papaya juice was extracted for analysis of bacterial and fungal growth. Nutrient agar (NA) and Potato Dextrose Agar (PDA) plates were prepared for counting colony forming units (CFU) of bacteria and fungus. The serial dilution method was followed. 9ml of sterile water was taken in 5 test tubes a in which the 1 mL of papaya juice was serially diluted from test tube 1 to test tube 5 and 100 microliter of diluted papaya juice was spread on NA and PDA plates. The same procedure was repeated for control samples. After every 5 days interval the microbial analysis was done in 15 days of storage. Then, the plates were placed in incubator at 37°C temperature for 5-7 days. After 5 days growth was observed and results was recorded after 7 days (Sharma et al., 2024).

The formulae used for counting colonies is given below:

$$\textbf{CFU/mL} = \frac{\textbf{number of colonies} \times \textbf{dilution factor}}{\boldsymbol{Volume\ of\ sample\ plated\ in\ mL}\ (\mathbf{0.1}\boldsymbol{mL})} \quad \text{equation (7)}$$

Chapter – 4

Results and Discussion

This section of study is related to results for edible coating applied on the surface of papaya for shelf life and quality analysis. The antimicrobial sensitivity test was performed for prepared coating formulation to detect its resistance for bacterial and fungal growth. After checking antimicrobial sensitivity, the coating was applied on the selected papaya fruits and stored at different temperatures. Then various attributes were measured for papaya fruit on which coating is applied and even for uncoated sample which was considered as control sample. The attributes are weight loss percentage, pH, titrable acidity, total soluble solids, water activity, color characteristics, total carotenoid test and microbial analysis. The samples were stored at three different temperatures 4°C, 10°C and 25°C for 15 days. But the samples stored at 25℃ survived only for 10 days as after 10^{th} day fungal growth increased and it spoiled the coated and control samples. More spoilage was observed on control as compared to coated ones. The tests were conducted on 0 day and after every 5 days interval in 15 days of storage. The analysis done for coated papaya along with control (uncoated) samples is discussed in the following section in detail. The reading for control and coated samples were compared to check the proficiency of prepared edible coating in extending the shelf life of post-harvested papaya.

4.1 Antimicrobial sensitivity test for prepared edible coating

Antimicrobial Sensitivity Testing (AST) is a laboratory procedure used to determine how effective an antimicrobial agent (antibiotic or antifungal) is against a specific microorganism (bacteria or fungus). It helps identify the most effective drug for treating infections. The antimicrobial sensitivity test was performed for detecting the resistance of bacterial growth by edible coating using nutrient agar plates. The prepared edible coating showed better resistance for bacteria, the zone of inhibition was measured and it was 33.09 cm2. The same test was performed for detecting resistance to fungus growth using potato dextrose agar plates the resistance was observed but it was less efficient than the resistance observed for bacteria. The zone of inhibition observed for fungal growth resistance has less area; it was 1.69 cm^2. This showed that the edible coating prepared has resistance to both bacteria and fungus and when it is applied on papaya it will help to resist the spoilage done by bacteria and fungus to the papaya. The results are shown in the fig 4.1 and 4.2. The bacterial strain used for detecting resistance was *Bacillus subtilis* and the fungus was *Aspergillus.* The results were seen positive as the resistance was observed against microorganisms.

Fig 4.1 shows the zone of inhibition observed for bacterial resistance

Fig 4.2 Shows the zone of inhibition observed fungal growth resistance

4.2 Application of prepared edible coating on papaya

The prepared edible coating was applied on papaya using the spraying method. When the coating gets dried it turned transparent which gives an attractive and fresh look to post harvested papaya. Due to the use of Moringa seed oil the surface of coated papaya gives shinny appearance than the uncoated ones (do Nascimento et al., 2023) The images below show difference between the coated and uncoated papayas.

Fig 4.3 Coated Papaya

Fig 4.4 Control (uncoated) Papaya

4.3 Physio-chemical attributes

Weight loss percentage Weight, which is consider as an indicator of freshness of fruits was observed for papayas stored at different temperatures. Lesser will be the weight loss of fruit, better will be the quality of fruit. The weight loss percentage calculated for coated and non-coated papaya showed the less loss for coated papayas, which indicates the results are positive. Weight loss was found to significantly increase through storage across three temperatures, with the uncoated (control) sample. The papaya stored at 4℃ showed less weight loss than 10℃ and 25℃ storages. The maximum weight loss was observed at 25℃. The weight loss was less in case of coated samples compared with uncoated papayas. The weight loss percentage for coated and uncoated samples are shown in the table 4.1.

Table 4.1 Showing weight loss percentage in 15 days storage period at 4°C, 10°C and 25°C.

Weight loss%	4°C		10°C		25°C	
	control	**coated**	**control**	**coated**	**control**	**coated**
0 day	0	0	0	0	0	0
5 days	2.94	2.7	12.95	6.65	22.96	10.61
10 days	6.7	2.4	17.3	12.77	35	24
15 days	6.2	2.9	29.97	16.33	-	-

As it can be seen in table 4.1 the weight loss percentage increased as the storage time and the temperature were increased. The figure 4.4 shows the graphical representation of the weight loss percentage in relation to temperature and storage time. Weight loss was less in coated samples because of moringa seed oil, as it helps to protect against the moisture loss (Al-Rashdi et al., 2024). The gas regulating properties starch helps as a barrier for gases also helps to reduce the weight loss (Oyom et al., 2022). The emulsion of starch and moringa seed oil helps the papaya to reduce weight loss by providing it a protective covering from environment. In control samples, the weight loss was observed because they not have any barrier to control moisture loss and gas exchange, due to which the weight loss was observed more in uncoated papayas. This helps us to find that prepared edible coating has efficient effect in preserving the papaya. The single reading was taken for weight change in papayas, which gives positive results for weight loss percentage. The weight loss percentage as compared with previous study of moringa oil-beeswax coating gives the similar results as the beeswax coating helped to reduce weight loss (Al-Rashdi et al., 2024), in same manner, the moringa seed oil- starch coating was efficient in reducing weight loss.

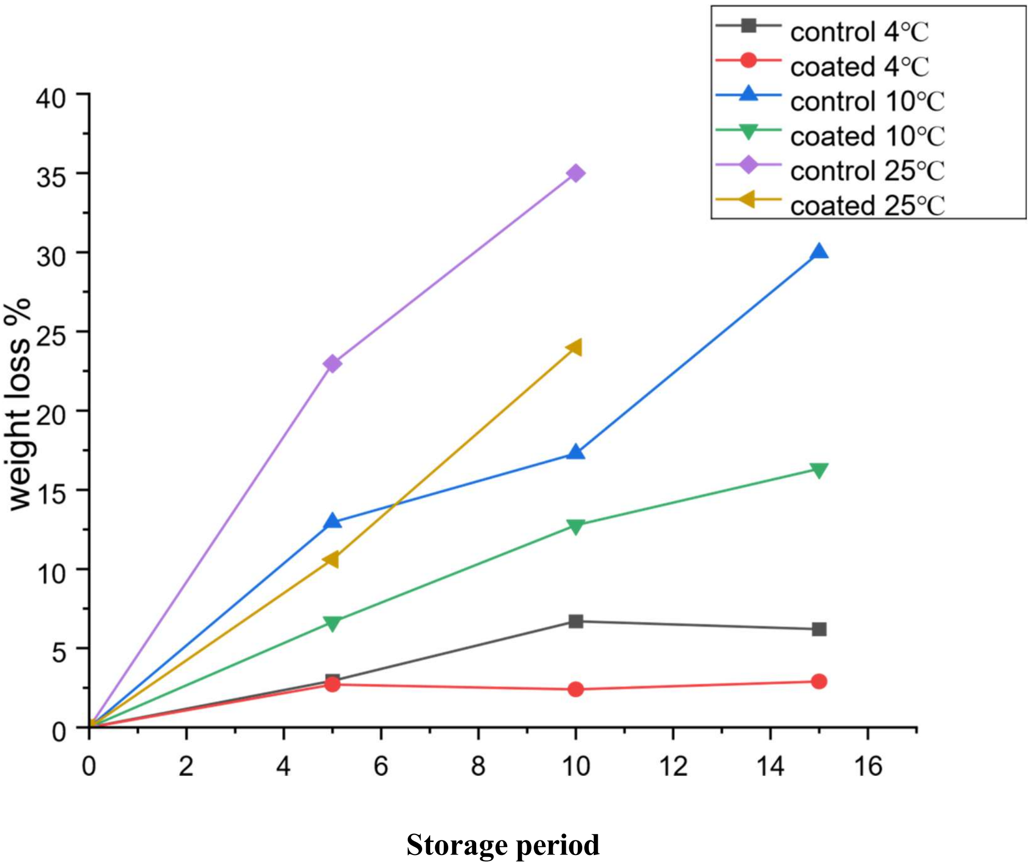


Fig 4.5 Graphical representation of weight loss percentage for coated and control samples at 4°C,10°C and 25°C temperature for 15 days storage.

pH The pH should be not too acidic for fruits, it should be near neutral of around 5 as the value decreases from 5 the fruit gets more acidic, pH plays major role in acidity of coated and uncoated fruits. The results for pH have indicated that the temperature and edible coating, both have significant effect on the pH value for papaya. The changes were observed in pH value for control and coated samples. The pH decrease for control samples was observed more as compared to coated samples, which suggests that the moringa seed oil-starch coating have protective effect on the pH stability. The control samples have shown more drop in pH values which ranged from 5.4

to 4. The range of pH for coated samples is from 5.5 to 5.0 which showed less drop in pH. The samples stored at 4°C has shown minor changes in pH. Small changes were detected in the samples stored at 10°C and the significant reduction in pH was observed for the papaya stored at 25°C within 10 days of storage. This signifies that pH for both coated and control samples decrease with rise in temperature. The data of pH range is given in below table 4.2.

Table 4.2 Showing pH changes during 15 days of storage at 4°C, 10°C and 25°C.

pH	**4°C**		**10°C**		**25°C**	
	control	**coated**	**control**	**coated**	**control**	**coated**
0 day	5.4 ± 0.05	5.5 ± 0.05	5.2 ± 0.11	5.5 ± 0.05	5.3 ± 0.05	5.3 ± 0.04
5 days	4.7 ± 0.05	5.5 ± 0.05	4.9 ±0.05	5.4 ± 0.05	4.8 ± 0.05	5.4 ± 0.05
10 days	4.3 ± 0.12	5.3 ± 0.05	4.7 ±0.05	5.3 ± 0.05	4.6 ± 0.05	5.1 ± 0.05
15 days	4.0 ± 0.12	5.3 ± 0.05	4.1± 0.05	5.3 ± 0.05	-	-

From the above given data the graph was prepared in which marginal decrease was observed for coated samples, and the control samples showed slight decrease. The temperature also plays significant role in changes in pH as the lower the temperature, the fruit has shelf- life more shelf life. Both the moringa seed oil-starch coated sample showed more changes at 25°C of temperature (Al-Rashdi et al., 2024). As papaya is low acid fruit its pH ranges from 5.4 to 6.0 if its pH goes below 5.0 the fruit gets more acidic which changes its taste and appearance. As the fruit ripens its acid content gets reduces, which means negligible changes in pH of papaya. The moringa seed oil and starch helped to prevent the changes in pH as it acts as a barrier to gas exchange (oxygen, Carbon dioxide and ethylene) which are involved in respiration process that affects the pH of papaya. The decrease in pH for uncoated (control) samples occurred due to production of organic acids and consumption of sugars, resulting in a more acidic conditions within fruits. The result for pH as compared with previous study (Al-Rashdi et al., 2024) showed some similar results which depicts the efficiency of developed edible coating. The graph for data given in table 4.2 is given in figure 4.6.

The pH and Titratable acidity (TA) are also related as the pH decreases the titratable acidity for fruits also decreases**.** If pH is 5 .2 or more the TA will be high but if pH is less than 4.5 than the TA will also be low. The concept of TA is discussed in next section briefly.

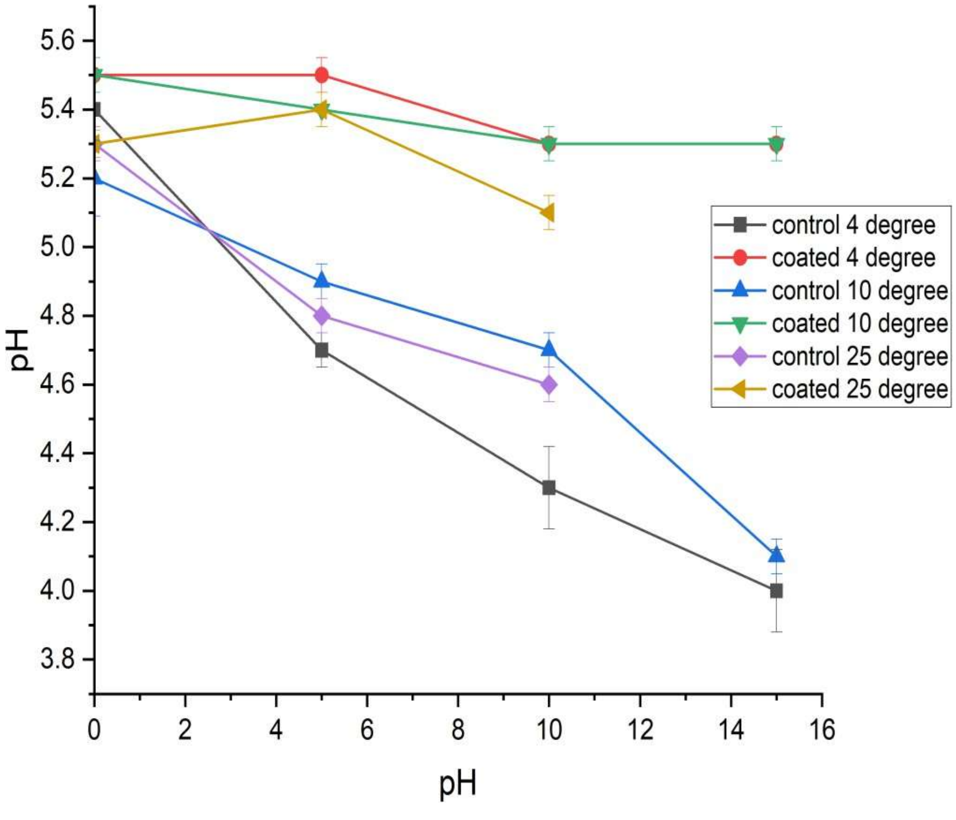


Fig 4.6 Graphical representation of pH changes for coated and control samples at 4°C,10°C and 25°C temperature for 15 days storage.

Titratable acidity (TA) The organic acids contributing to the papaya are citric acid and malic acid. it is believed that respiration of fruits utilizes these organic acids as substrate resulting in decrease in TA values during the post-harvest storage (Valero et al., 2013) which was evident in Table 4.3 for all the samples, with a prominent decrease in the uncoated sample. More will be the titratable acidity, more the fruit will be look fresh and eatable. The TA value decreased for coated fruits but decreases slower as compared to uncoated samples. The initial value of titratable acidity was 0.35 which reduces to 0.21 on the 15th day of analysis at 4°C temperature for control samples and as changes in TA were less for coated samples, coated samples had shown relatively higher TA values. Whereas, for 10°C storage the TA value reduced from 0.26 to 0.17 for control samples and 0.26 to 0.21for coated samples. At 25°C storage TA value changes to 0.20 at 10th day of storage. Thus, edible coatings might be effective in reducing the metabolic changes occurring in fruit or the rate of respiration thus delaying the consumption of organic acids (Raju et al., 2023). The table 4.3 shows the data for recorded titratable acidity values at three different temperatures for 15 days of storage. The edible coating showed efficiency in preserving the TA more to prevent post-harvested losses in papaya at three temperatures. The calculations were done using equation (3) as given in methodology.

Table 4.3 Showing Titratable acidity data during 15 days of storage at 4°C, 10°C and 25°C.

TA	4°C		10°C		25°C	
	control	coated	control	coated	control	coated
0 day	0.35 ± 0.07	0.35 ± 0.07	0.26 ± 0.11	0.26 ± 0.11	0.26 ± 0.11	0.26 ± 0.11
5 days	0.33 ± 0.06	0.33 ± 0.12	0.23 ± 0.08	0.25 ± 0.07	0.22 ± 0.07	0.24 ± 0.12
10 days	0.26 ± 0.11	0.23 ± 0.12	0.21 ± 0.06	0.22 ± 0.06	0.20 ± 0.08	0.21 ± 0.06
15 days	0.21 ± 0.06	0.22 ± 0.11	0.17 ± 0.06	0.21 ± 0.11	-	-

The graphical representation of above data shows the almost the downward shift for both the samples. The moderate decrease was observed in the TA value for coated and control samples at three different temperatures. The samples taken as control showed for decrease then the coated ones. The TA value for coated papaya at 4°C after 15 days was observed to be same to the TA value for 25°C after 10 days. This reflects that the papaya stored at 4°C shows better results than the 25°C storage. It was also observed that the coated papaya was preserved more while compared to non-coated samples. As the pH decreased, the TA value also decreased. The TSS : TA results compared with the study for enhancement of the shelf-life of papaya (Raju et al., 2023) showed differences in values but the ratio for developed edible coating has followed the decreasing trend. The graph for table 4.3 is given in figure 4.7.

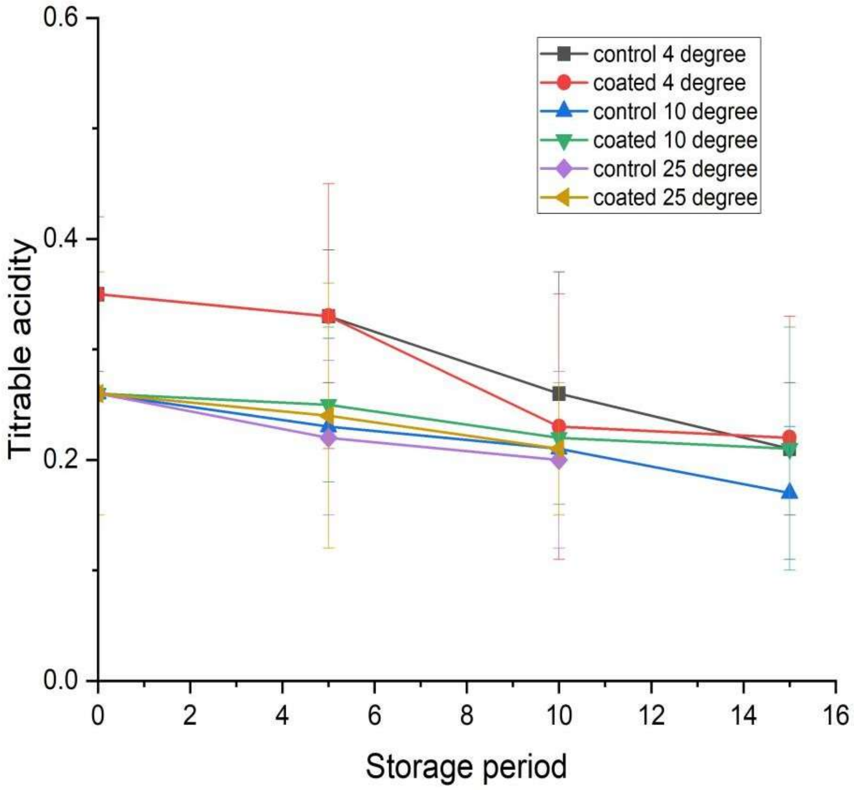


Fig 4.7 Graphical representation of Titratable acidity (TA) for coated and control samples at 4°C,10°C and 25°C temperature for 15 days storage.

Total soluble solids (TSS) TSS, refers to the concentration of dissolved sugars in the fruit juice, its key indicator for sweetness of fruits and is measured in degrees Brix. Ripening of fruit with time or storage is directly related to increase in TSS content owing to the solubilization of complex carbohydrates into simpler structures of sugar which is evident in all the samples. The higher the TSS value, more the sweet will be fruit. The initial value for TSS recorded was 7.2°Bx and it remained same for 5 days after that when on 10th day the values were observed there was increase in the values. By last day of storage, gradual increase was observed for coated and control samples. The breakdown of carbohydrates, partial hydrolysis of proteins and decomposition of glycosides during respiration causes decrease in total soluble solids but in coated samples this breakdown was less so the TSS for coated samples was high as compared to control (Athmaselvi et al., 2013). The data collected for TSS is given below in the table 4.4.

Table 4.4 Showing Total soluble solids content for 15 days of storage at 4°C, 10°C and 25°C.

TSS	4°C		10°C		25°C	
	control	**coated**	**control**	**coated**	**control**	**coated**
0 day	7.6 ± 0	7.6 ± 0.1	7.2 ± 0.1	7.2 ± 0.1	7.8 ± 0.1	7.8 ± 0
5 days	8.4 ± 0.1	8.0 ± 0.1	8.4 ± 0.1	8.8 ± 0.1	8.9 ± 0	8.8 ± 0.1
10 days	8.9 ± 0.1	8.8 ± 0.1	9.2 ± 0.1	9.0 ± 0.1	10 ± 0.1	9.7 ± 0.1
15 days	9.2 ± 0.1	9.0 ± 0.1	9.5 ± 0.1	9.2 ± 0	-	-

The graphical representation of above data shows moderate decrease for control samples and slight decrease for coated samples. The coated sample showed less increase as compared to the non-coated samples. The values ranged from 7.2°Bx to 10°Bx with the passage of time. The temperature has also shown effect on the TSS value of papaya. As the temperature was increased the more increase in TSS values was observed (Al-Rashdi et al., 2024). The results were similar to the previous study (Al-Rashdi et al., 2024) which proves the prepared edible coating is efficient. The fig 4.8 shows the data representation for TSS.

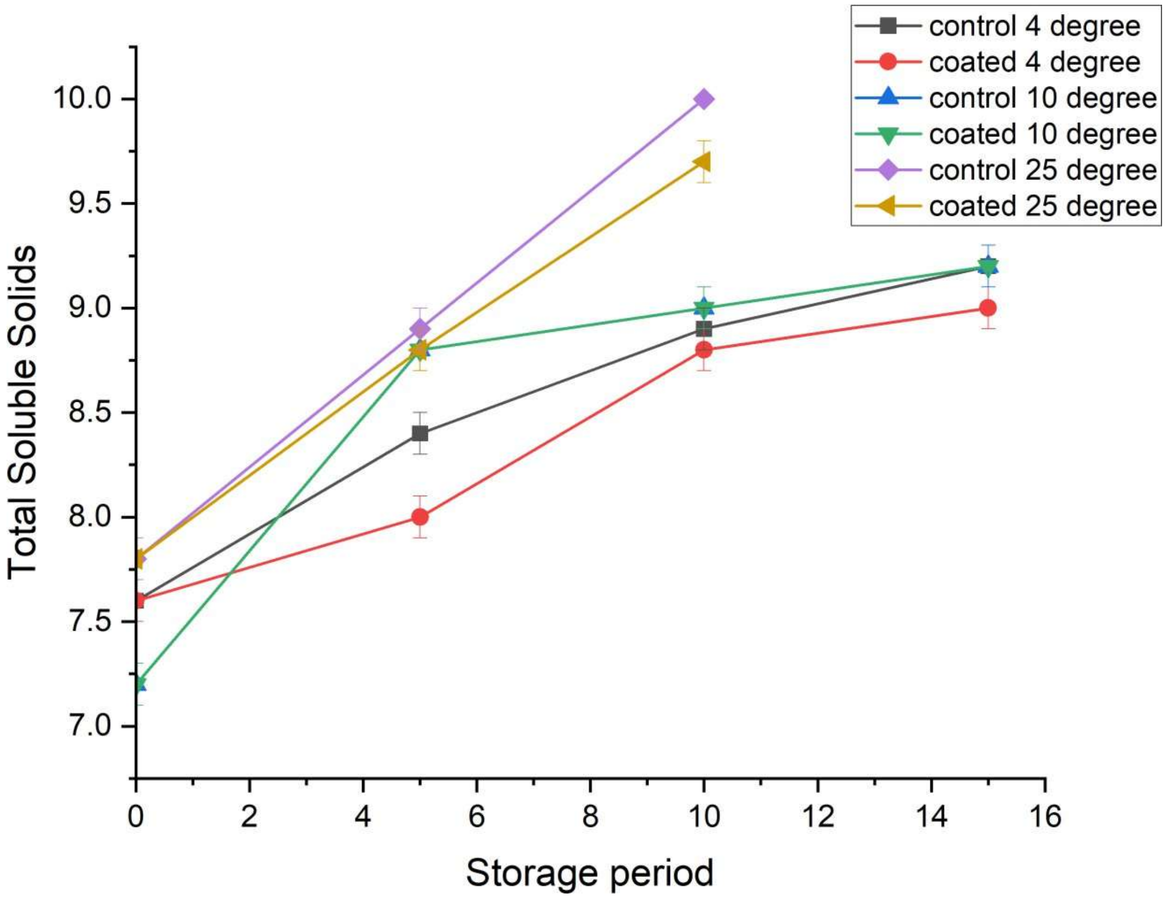


Fig 4.8 Graphical representation of TSS for coated and control samples at 4°C,10°C and 25°C temperature for 15 days storage.

Total soluble solids: Titratable acidity (TSS: TA) The ratio TSS to TA is used to represent the sweetness-to-sourness balance in fruits and fruit juices. A higher ratio indicates the better taste and ripening of the fruit, while lower the ratio slow will be the ripening process and less sweet will be the taste of fruit. In this study, we can see that the ratio increased as the time passes and the temperature is increased. But for the coated papayas lesser increase was observed then the uncoated ones, which indicated the slow ripening of coated papayas and increase in shelf-life of post-harvested papayas. The TSS ratio TA was obtained and is given in the table 4.5. The data increased as the time of storage increased for both the samples (Raju et al., 2023). The values were calculated using equation (4). The total soluble solids changes were recorded for both the control and coated samples as described in above sections and the titratable acidity was calculated for control and coated samples as given above. Then, these both values were used to calculate the ratio TSS:TA.

Table 4.5 Showing TSS: TA content for 15 days of storage at 4°C, 10°C and 25°C.

TSS : TA	4°C		10°C		25°C	
	control	coated	control	coated	control	coated
0 day	21.7 ± 2.5	21.7 ± 2.5	27.6 ± 0.7	27.6 ± 0.6	30± 0.6	30 ± 0.3
5 days	25.4 ± 1.1	24.2 ± 0.5	36.5 ± 1.1	35.2 ± 0.5	40.4 ± 0.7	36.6 ± 0.4
10 days	34.2 ± 0.7	38.2 ± 0.7	43.8 ± 0.5	40.9 ± 1	50 ± 0.5	46.1 ± 1.4
15 days	43.1± 0.6	40.9 ± 0.7	55.8 ± 1.6	43.8 ± 0.4	-	-

The above data is represented in the graph which follows an upward trend. The TSS: TA ratio has shown increase in values with increase in temperature which has effect on shelf-life of fruits. At 25°C the papayas ripened earlier than the 4°C and 10°C. Many variations were observed in the data. The TSS: TA showed increase in values with the storage period of 15 days also. The ratio for control samples showed higher values than the papaya coated with Moringa seed oil-starch edible coating, which gives positive results for the prepared edible coating. The values for prepared edible coating show similarity with the values of previous study (Raju et al., 2023). The graphical representation of the above given data in fig 4.9.

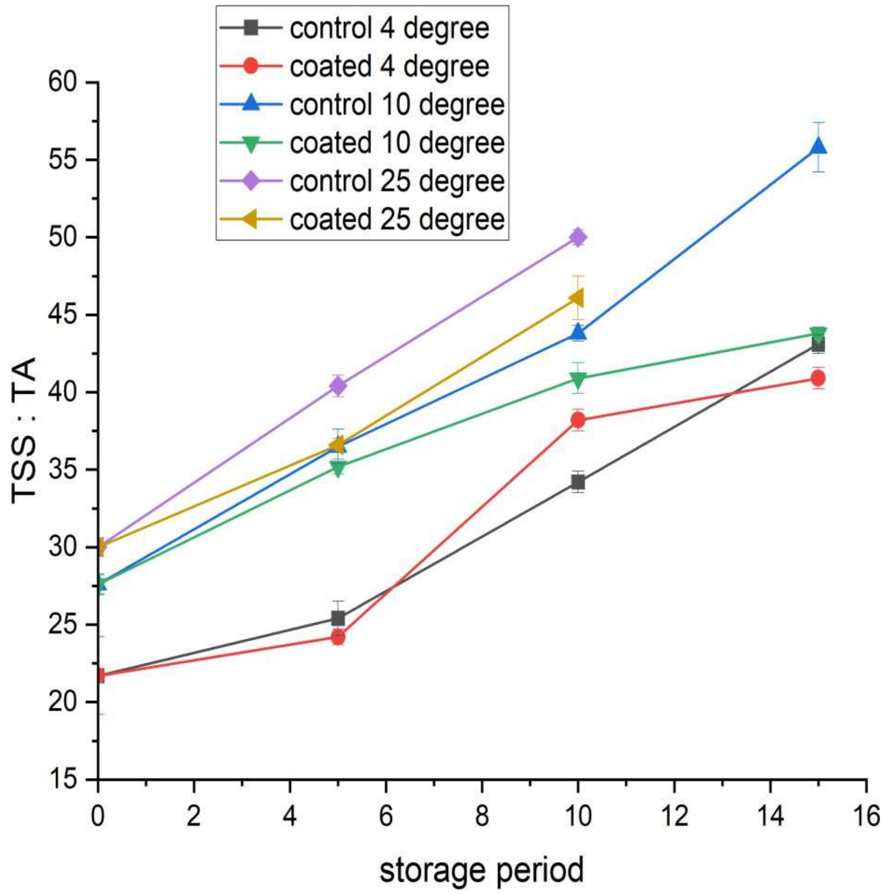


Fig 4.8 Graphical representation of TSS : TA for coated and control samples at 4°C,10°C and 25°C temperature for 15 days storage

Water activity The water loss in fruits decreases the water activity of fruits with the passage of time. More will be the water activity, earlier will be the ripening of fruit. As the storage time of fruits is increased the water loss increased which effects the ripening function and appearance of fruits. The water activity for fully ripen papaya lies between 0.98 – 0.99. The water activity for partially ripened papayas was measured which was 0.97 – 0.98 for control and coated sample on 0 day. Then, papayas were stored at three different temperatures 4°C, 10°C and 25°C for 15 days due to which changes were observed for water activity. As the time increases the papayas water activity decreased from 0.98 to 0.92 for control samples but very less changes in water activity were observed for coated samples it ranged from 0.92 to 0.95.the loss of water was less in case on coated samples than the uncoated samples. The less will be the water loss more the time fruit can survive and the slow will be the ripening process which help to reduce post-harvest losses. In accordance, to temperature maximum decrease in water activity was observed for 25°C and least changes at 4°C. At 10°C storage the control sample showed 0.92 at 15^{th} day of analysis whereas coated sample had 0.94 at 15^{th} day (Zamora & Chirife, 2006). The decrease in water activity is related to the weight loss of papayas. As the water activity decreases, the weight loss was increased. The table 4.5 shows the results for water activity.

Table 4.5 Showing Water Activity for 15 days of storage at 4°C, 10°C and 25°C.

Water activity	**4°C**		**10°C**		**25°C**	
	control	**coated**	**control**	**coated**	**control**	**coated**
0 day	0.97 ± 0.01	0.97 ± 0.01	0.97 ± 0.007	0.97 ± 0.01	0.98 ± 0.00	0.98 ± 0.01
5 days	0.96 ± 0.01	0.96 ± 0.01	0.95 ± 0.00	0.96 ± 0.01	0.98 ± 0.01	0.98 ± 0.01
10 days	0.94 ± 0.01	0.95 ± 0.01	0.94 ± 0.01	0.94 ± 0.00	0.94± 0.00	0.95 ± 0.01
15 days	0.94 ± 0.01	0.94 ± 0.00	0.92 ± 0.01	0.93 ± 0.01	-	-

The graphical representation of above data has shown moderate decrease in the water activity with the effect of temperature and time. The results for water activity were relevant but has shown different values from the study which was followed (Zamora & Chirife, 2006). The fig 4.9 gives the graphical representation for the water activity. The prepared edible coating showed positive results in preserving the fruits.

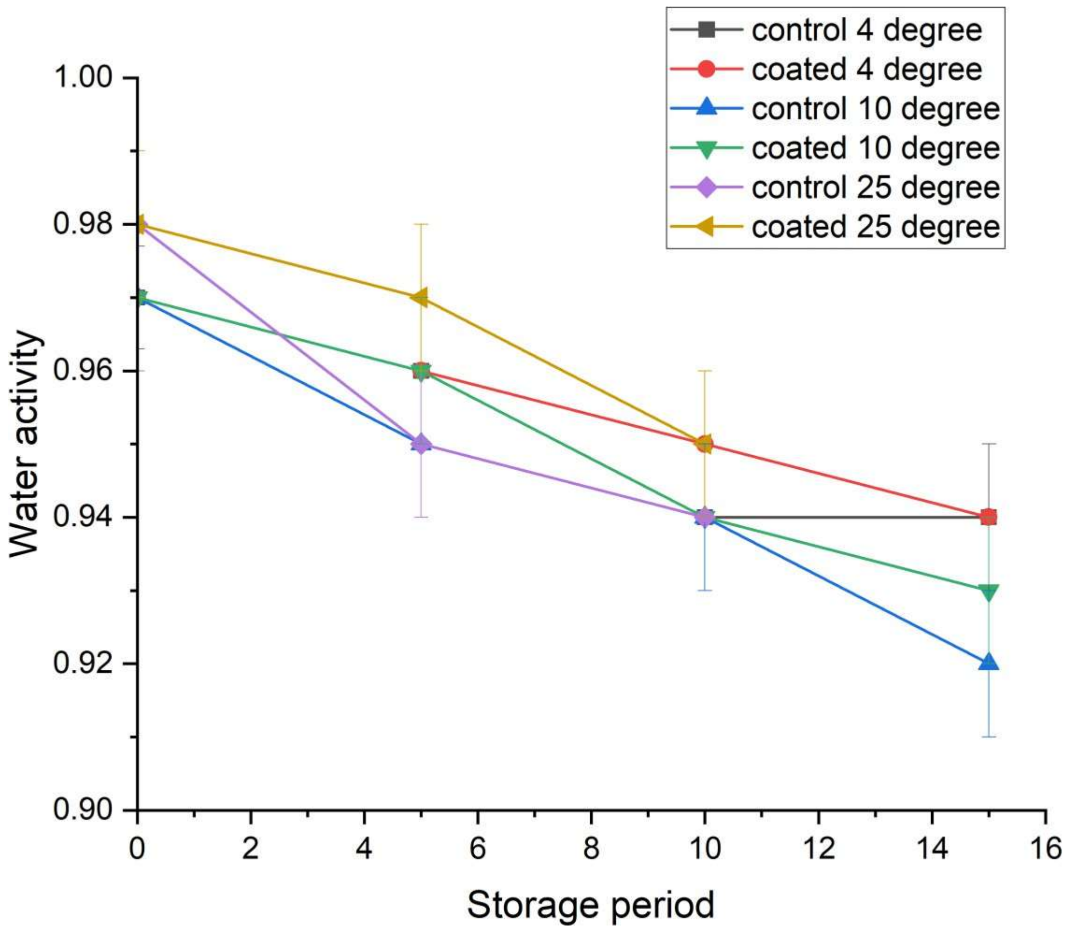


Fig 4.9 Graphical representation of water activity for coated and control samples at 4°C,10°C and 25°C temperature for 15 days storage.

Color characteristics Color is the most important quality attribute associated with fresh-cut fruits, which plays a key role in determining the consumer's preference and acceptability towards food. It is perceived as a part of total appearance, which is the visual recognition and assessment of the surface and subsurface properties of the food material. Color characteristics of the papaya were monitored by measuring L* (lightness), a* (redness), and b* (yellowness), color change, hue, and chroma values during the 15 days of storage period at 4°C, 10°C and 25°C. Then, the color difference (ΔE) was calculated using the equation (5) as given in methodology. The color change increased for uncoated sample which indicates fast ripening of control samples as compared to the coated papayas. As the edible coating applied on papaya acted as a protective covering, and reduced the release of ethylene which leads to the ripening of papaya and causes the color change. For the uncoated samples the ethylene release was not controlled by any kind of covering due to which uncoated samples ripened earlier and shows more color change. The values for color change also vary according to temperature, the rise in temperature increases the value for color change which indicates that the increase in temperature causes the earlier ripening of post-harvested papayas. The changes in ripening process were observed faster in control samples as compared to coated ones. (López-Díaz et al., 2025) The table 4.6 depicts the color difference for papayas stored at different temperatures.

Table 4.6 (a) Showing color difference (ΔE) for 15 days of storage at 4°C, 10°C and 25°C.

ΔE	4°C		10°C		25°C	
	control	**coated**	**control**	**coated**	**control**	**coated**
0 day	0	0	0	0	0	0
5 days	12.49 ± 1.49	12.33 ± 3.25	13.89 ± 0.52	12.96 ± 1.26	23.7 ± 3.45	22.65 ± 1.87
10 days	16.78 ± 2.51	15.67 ± 1.32	22.43 ± 1.58	19.87 ± 1.71	28.64 ± 2.14	25.76 ± 1.56
15 days	17.67 ± 1.26	16.9 ± 1.78	27.76 ± 3.72	24.64 ± 2.84	-	-

As it can be observed from given data the increase for control samples is more than coated samples. The color change on 0 day was 0 as the L*, a* and b* values on that days were subtracted from as the L_0*, a_0*and b_0* which were 0 on that day so the value after calculation was 0. The L*, a* and b* values of 0 day were taken as control values for calculating color change on other days of storage. The graphical representation of table 4.6 is given in fig 4.10.

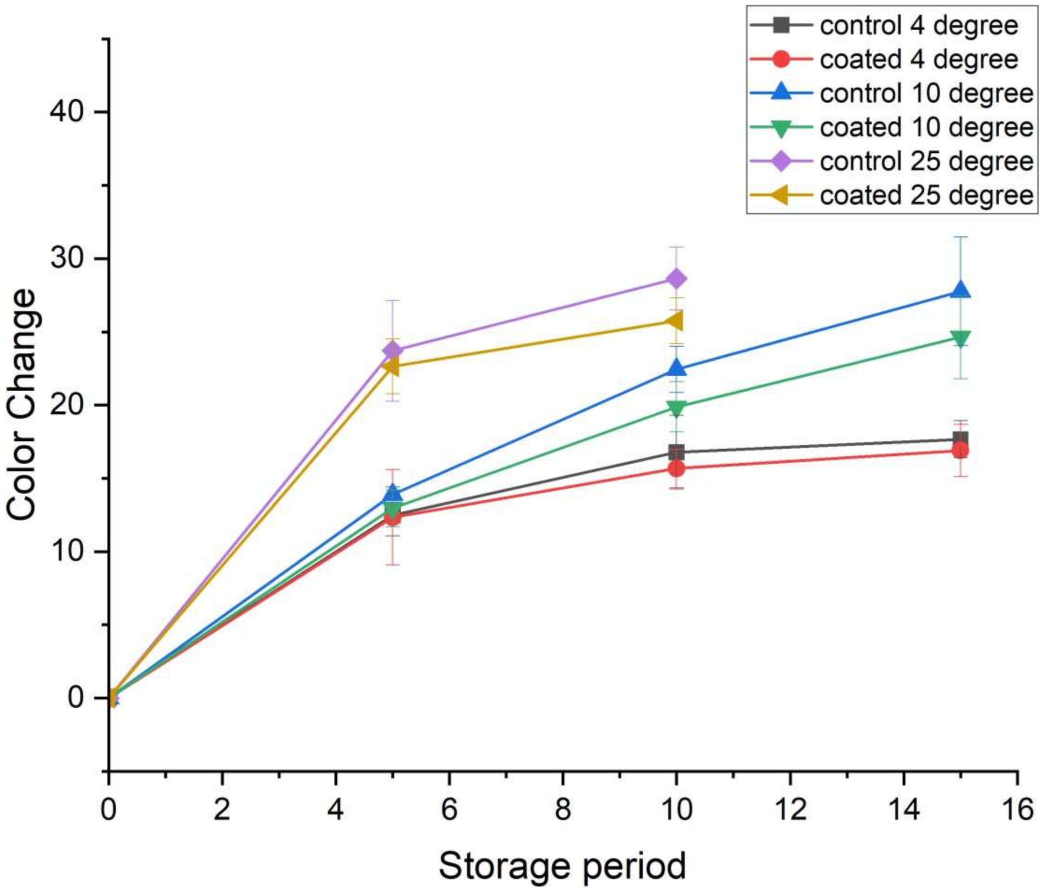


Fig 4.10 (a) Graphical representation of color difference for coated and control samples at 4°C,10°C and 25°C temperature for 15 days storage

The color change in coated and non-coated papayas can be seen in below given fig 4.11, 4.12 and 4.13 at the 4°C, 10°C and 25°C. The color gets yellowish-orange as the time increased, which indicates the ripening of papaya. The temperature also effected the color change as at low temperature less change was seen and at 10°C and 25°C. At 25°C maximum spoilage to papaya was done by fungus and effected the appearance of fruit.

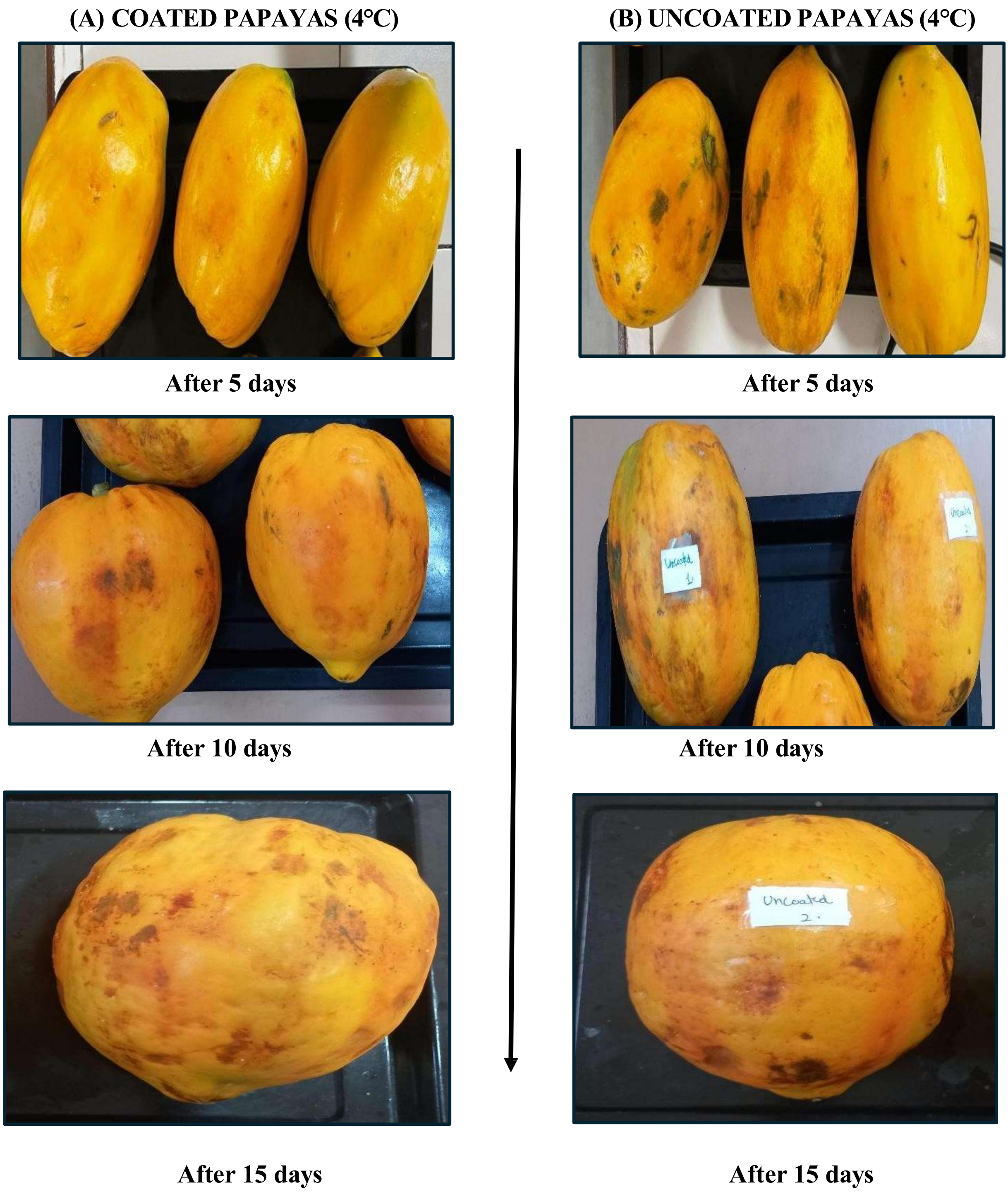


Fig 4.11 (A) Papayas coated with edible coating showing color change in 15 days of storage at 4°C. (B)uncoated papayas showing color change in 15 days of storage at 4°C.

(A) COATED PAPAYAS (10°C) **(B) UNCOATED PAPAYAS (10°C)**

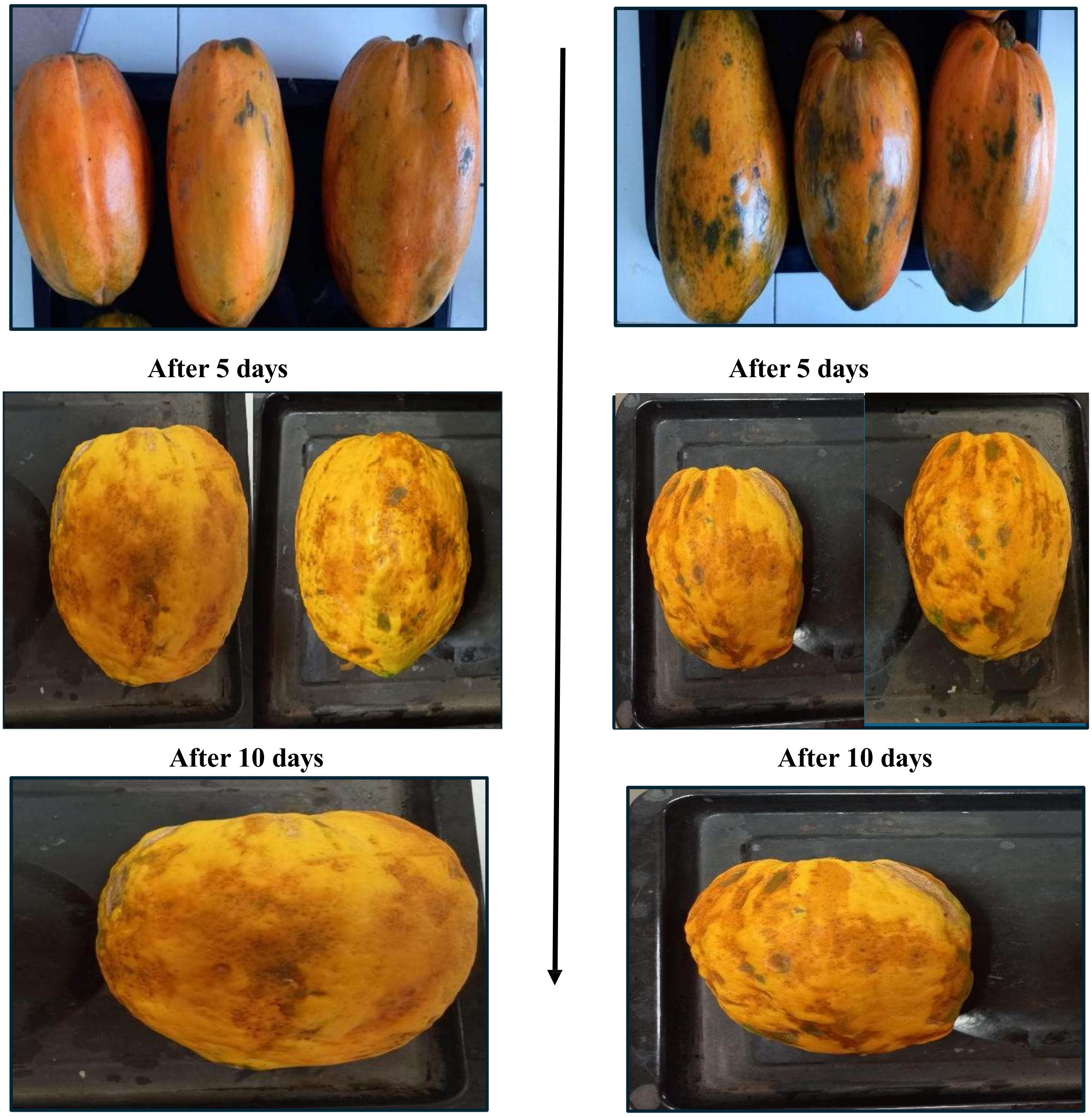


Fig 4.12 (A) Papayas coated with edible coating showing color change in 15 days of storage at 10°C. (B)uncoated papayas showing color change in 15 days of storage at 10°C.

(A) COATED PAPAYAS (25°C)

After 5 days

After 10 days

After 15 days

(B) UNCOATED PAPAYAS (25°C)

After 5 days

After 10 days

After 15 days

Fig 4.13 (A) Papayas coated with edible coating showing color change in 15 days of storage at 25°C. (B)uncoated papayas showing color change in 15 days of storage at 25°C.

Chroma values Chroma, a measure of color saturation or intensity exhibited a gradual increase in all the samples over the period of storage. The uncoated (control) sample showed a sharp increase in chroma and had the highest value of 47.87 by day 15 of storage (López-Díaz et al., 2025). The increase in coated papaya was also observed but it was less as in comparison to uncoated samples. The chroma values for papayas are showed in the table 4.6(b).

Table 4.6 (b) Showing chroma value for 15 days of storage at 4°C, 10°C and 25°C.

Chroma value	**4°C**		**10°C**		**25°C**	
	control	**coated**	**control**	**coated**	**control**	**coated**
0 day	38.65 ± 1.50	38.65 ± 1.50	39.64 ± 1.90	39.64 ± 0.45	40.22 ± 1.07	40.22 ± 0.64
5 days	42.64 ± 0.08	39.45 ± 1.60	42.94 ± 0.68	41.62 ± 1.56	41.54 ± 0.34	40.98 ± 0.48
10 days	43.54 ± 0.90	42.64 ± 1.80	44.66 ± 0.43	42.98 ± 1.80	45.67 ± 1.87	41.32 ± 0.06
15 days	46.87 ± 0.60	45.98 ± 0.83	47.87 ± 1.40	46.78 ± 1.05	-	-

The graph for the obtained data is given in fig 4.11. The increase in values was observed with relation to time and temperature for storage. Both the attributes have effect on chroma angle of papayas. The maximum change was observed for non-coated samples at 10°C. The chroma angle ranged from 37 to 48 which indicates yellow-orange color which increased as the fruit was undergoing the ripening stages. As the chroma angle increases, the fruit is considered to get ripened with the in time and temperature.

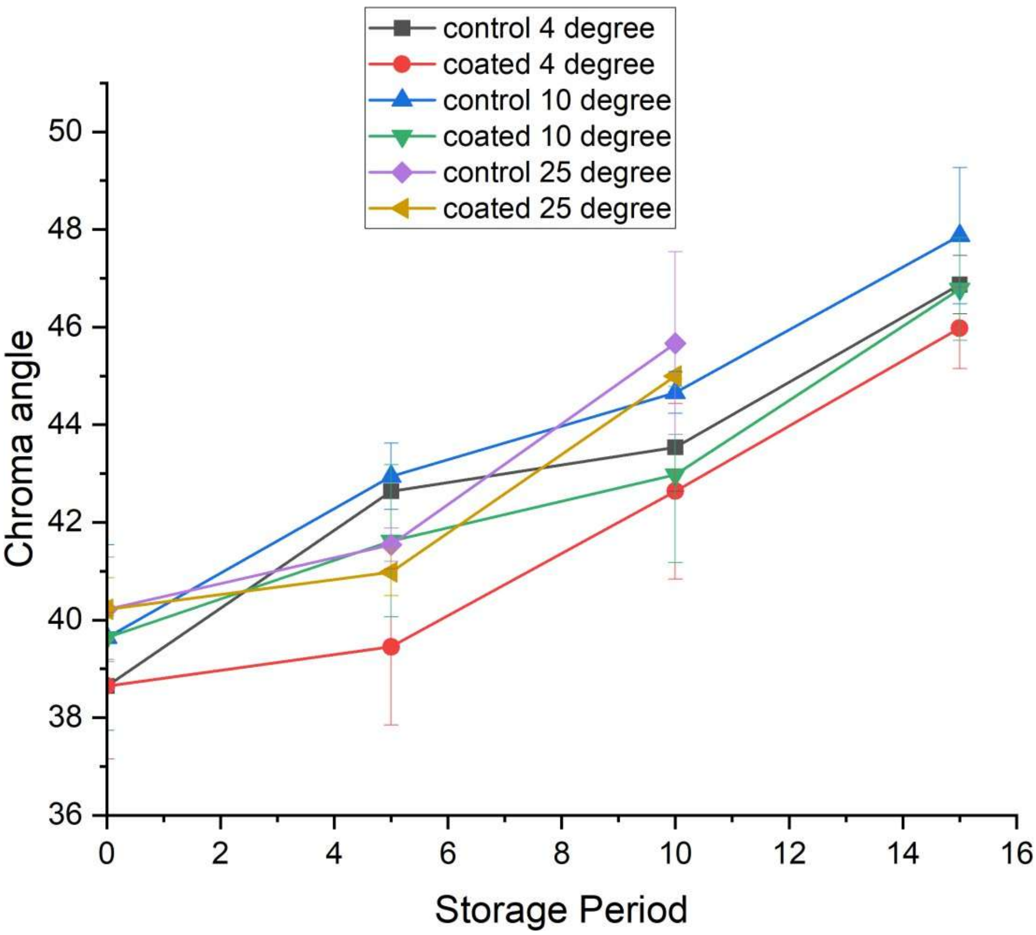


Fig 4.14(a) Graphical representation of chroma angle for coated and control samples at 4°C,10°C and 25°C temperature for 15 days storage.

Hue angle, Hue angle, a frequent indicator of color in food products, showed no definite trend among the coated as well as uncoated samples. Various pigments like lycopene, anthocyanin, carotene are synthesized during ripening and thus may have affected the hue and chroma values (López-Díaz et al., 2025). The hue angle has shown changes in the values for coated and non-coated samples. The table 4.8 depicts the information for hue angle.

Table 4.6 (c) Showing hue angle value for 15 days storage at 4°C, 10°C and 25°C.

Hue angle	4°C		10°C		25°C	
	control	coated	control	coated	control	coated
0 day	67.98 ± 0.72	67.98 ± 0.72	51.95 ± 1.56	51.95 ± 0.76	49.1 ± 0.76	49.1 ± 1.22
5 days	62.06 ± 1.23	56.78 ± 0.31	38.44 ± 0.58	59.8 ± 0.43	43.19 ±1.58	48.39 ± 0.78
10 days	43.66 ± 0.64	50.25 ± 1.56	61.11 ± 0.79	68.82 ± 0.64	40.25 ± 1.66	44.15 ± 1.45
15 days	36.07 ± 0.78	40.36 ± 1.87	50.25 ±0.87	59.04 ± 0.97	-	-

The graph of given data is shown in fig 4.11. the hue angle values not follow a trend as the values increased or decreased according to temperature variations for both control and coated samples. The papayas stored at 4°C and 25°C followed the downward shift and for 15th to 10th day of storage respectively. The papaya stored at 10°C followed the decreasing trend to 10th day of storage than its hue angle increased after 15 days for control and coated samples but for coated papaya the less change was recorded than the control. The value of hue angle indicates the green-yellow-orange color change followed by the papaya for both control and coated samples. The delay change in color was observed in coated papayas at the 4°C, then at 10°C and 25°C.

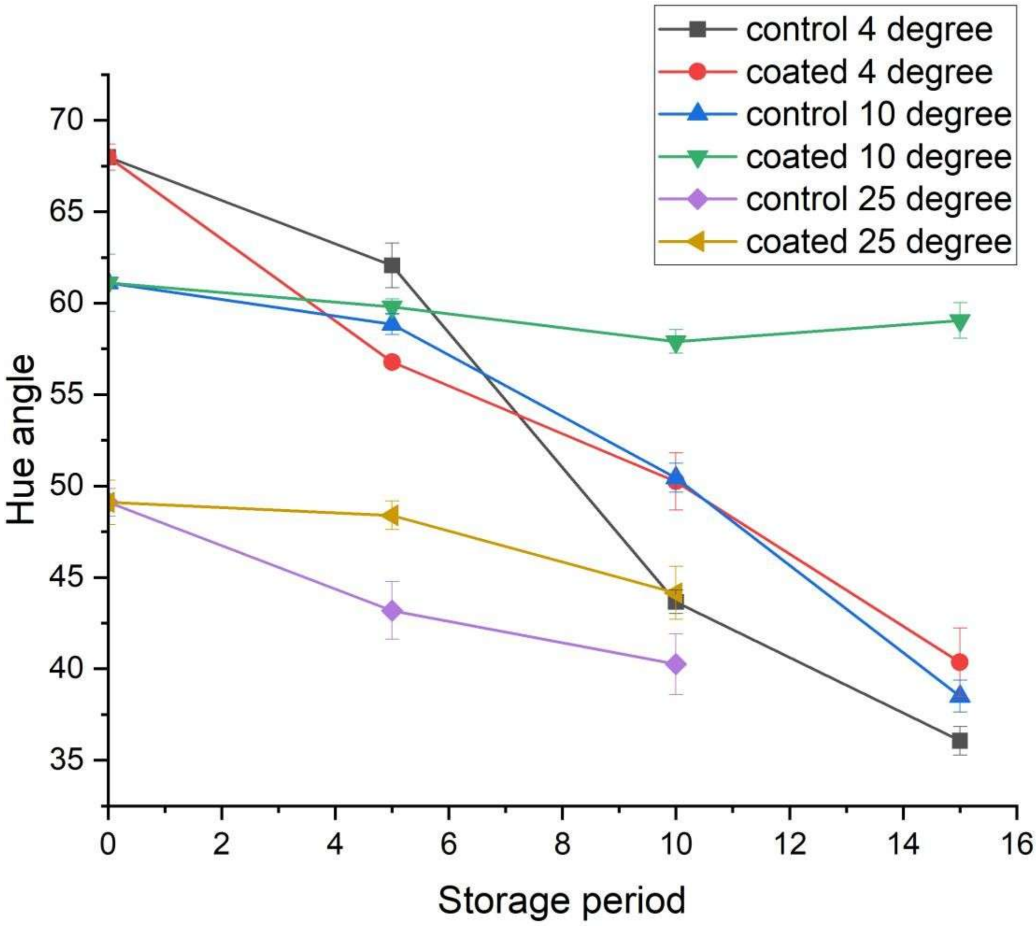


Fig4.15 (b) Graphical representation of hue angle for coated and control samples at 4°C,10°C and 25°C temperature for 15 days storage.

4.4 Total Carotenoid content

Carotenoids are the kind of pigments present in papaya responsible for imparting yellow-orange color to papaya. As the papaya gets ripen with time the amount of these pigments increases, which indicates the ripening od papaya at different temperatures and with time. The carotenoids were extracted from papaya and their content was measured for every fruit. As the carotenoids are responsible for imparting the color to papaya. The color difference increased for control samples more as compared to coated one, in same way, the carotenoids content increased more for control samples than the coated ones. Change in color of papaya is indicator of its ripening, change in color occurred due to beta-carotene pigment. The difference or increase for carotenoid content was not observed to be very high the values increased from 1.321 to 1.492. Maximum change was observed at 25°C at 10th day of storage and minimum change was observed at 4°C (do Nascimento et al., 2023). The table 4.9 depicts the information about total carotenoid content for 15 days storage at 4°C, 10°C and 25°C.

Table 4.7 Showing total carotenoid content for 15 days of storage at 4°C, 10°C and 25°C.

TCT	4°C		10°C	
	control	**coated**	**control**	**coated**
0 day	1.321 ± 0.306	1.321± 0.306	1.055 ± 0.123	1.055 ± 0.123
5 days	1.446 ± 0.056	1.432 ± 0.074	1.163 ± 0.058	1.145 ± 0.236
10 days	1.480 ± 0.480	1.436 ± 0.158	1.429 ± 0.124	1.326 ± 0.065
15 days	1.492 ± 0.310	1.482 ± 0.165	1.476 ± 0.109	

TCT	25°C	
	control	**coated**
0 day	1.233 ± 0.012	1.233 ± 0.012
5 days	1.426 ± 0.405	1.296 ± 0.065
10 days	1.421 ± 0.350	1.420 ± 0.056
15 days	-	-

The graph in fig 4.13 gives information about the total carotenoid content that is present in control and coated papayas. The Carotenoid content follows an upward trend. By the 15th day of storage very negligible change was observed in the total amount of carotenoids present in the coated and control samples stored at 4°C and 10°C. For 25°C the control sample carotenoid content was 1.421 and for coated sample it was 1.420 which was negligible difference. The amount of total Carotenoids content present in Papaya can also help to see the difference between fully ripened, partially ripened and unripen papaya. The results for carotenoid content were convenient as compared to previous studies which showed almost similar values (do Nascimento et al., 2023).

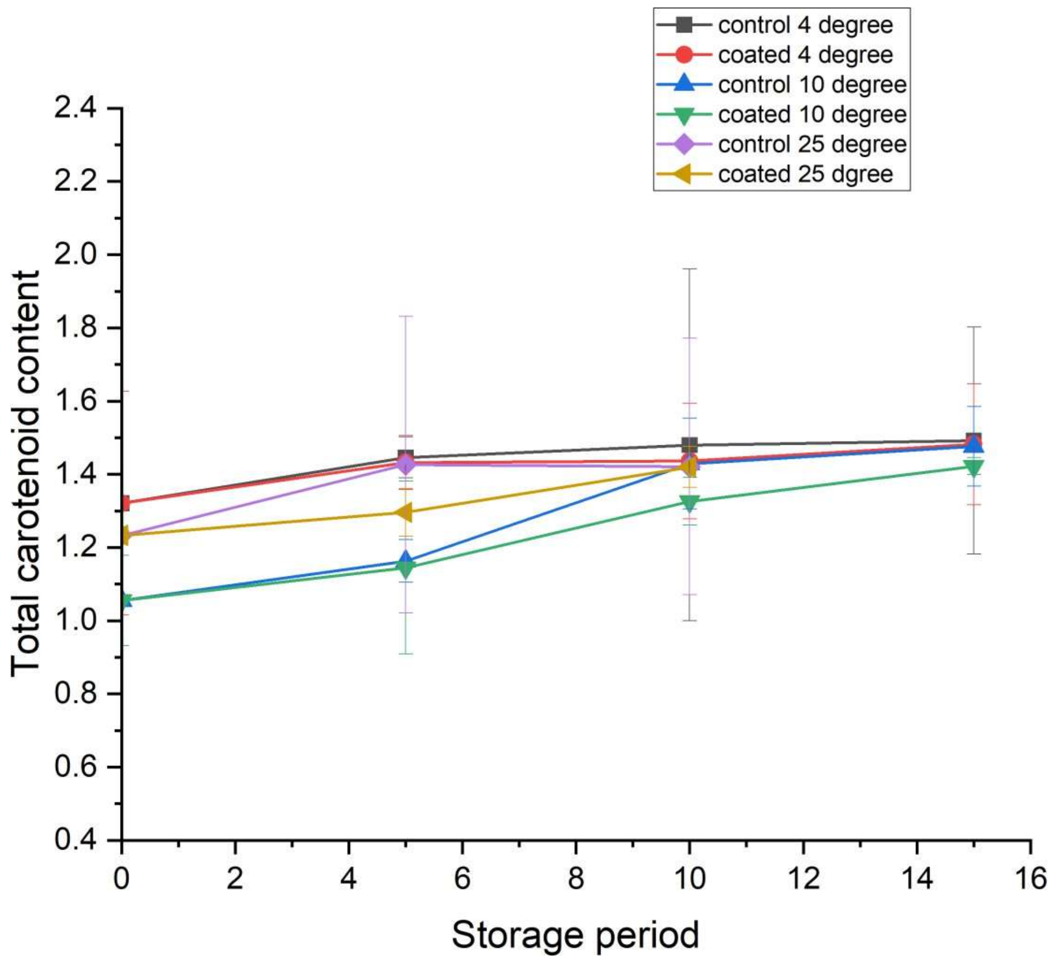


Fig 4.16 Graphical representation of total carotenoid content for coated and control samples at 4°C,10°C and 25°C temperature for 15 days storage.

4.5 Microbial analysis

Microbial analysis was done for bacterial and fungal count using serial dilution method. All the samples were analyzed during the entire storage period for total bacterial and fungal count. It was observed that the samples stored at 4°C have least fungal and bacterial count as compared to the samples stored at 10°C and 25°C. In control samples more microbial growth was observed than the coated samples. The maximum spoilage was observed for coated and uncoated papaya stored at 25°C. As 25°C is considered as more relevant temperature at which the fungal growth is supported so the samples stored at 25°C survived only for 10 days. The highest bacterial count was observed for 10°C after 15 days for control sample (372 CFU/ml) and maximum fungal count was observed at 25°C after 15 days of storage which was 516 CFU/ml for control samples. The minimum bacterial count was observed for coated samples kept at 4°C after 5 days of storage and lowest fungal growth was observed at 4°C after 5 days storage. On 10th day of analysis, the bacterial and fungal growth was observed on coated samples stored at 25°C. Papayas stored at 4°C and 10°C were not spoiled by 10th day, spoilage was observed by 15th of day storage. The CFU/ml count for bacterial and fungal growth is shown in below given table 4.9.

Table 4.8 (a) Showing CFU/ml for bacterial count samples stored at 4°C, 10°C and 25°C for control and coated.

CFU/ml (Bacteria)	**4°C**		**10°C**		**25°C**	
	control	**coated**	**control**	**coated**	**control**	**coated**
0 day	34 ± 2.86	34 ± 2.86	72 ± 3.52	72 ± 3.52	28 ± 5.64	28 ± 5.64
5 days	72 ± 3.5	37 ± 3.5	83 ± 2	79 ± 6	93 ± 5.8	77 ± 6.5
10 days	53 ± 4.6	32 ± 10	193 ± 5	183 ± 8	183 ± 6.7	115 ± 8.9
15 days	136 ± 2.7	116 ± 12	372 ± 17	274 ± 5.9	-	-

Table 4.8 (b) Showing CFU/ml for fungal count samples stored at 4°C, 10°C and 25°C for control and coated

CFU/ml (Fungal)	4°C		10°C		25°C	
	control	**coated**	**control**	**coated**	**control**	**coated**
0 day	54 ± 5.6	54 ± 5.6	87 ± 6.4	87 ± 6.4	64 ± 8.6	64 ± 8.9
5 days	94 ± 8.9	89 ± 7.8	112 ± 11	98 ± 14.8	223 ± 9.7	207 ± 4.5
10 days	156 ± 12.8	164 ± 9.8	98 ± 13.45	88 ± 12	516 ± 6.5	498 ± 13.7
15 days	224 ± 13	187 ± 6.4	281 ± 8.7	245 ± 8.4	-	-

The graphical representation for bacterial and fungal count follows an upward trend. As the storage time increases, more spoilage and degradation of papaya was observed. For the samples stored at 25°C the fungal spoilage reached too high that the samples were not able survive after 10th day. Even on day 7 - 8 papayas stored at 25°C were observed, their surface was covered with fungal growth uncoated samples showed more deterioration than the coated ones. The papayas stored at 10°C, after 10th day showed sharp increase in CFU/mL count this might has happen because the fruit followed senescence and after that the bacterial growth reached to peak. The fig 4.14 and 4.15 shows the graphs for bacterial and fungal growth respectively.

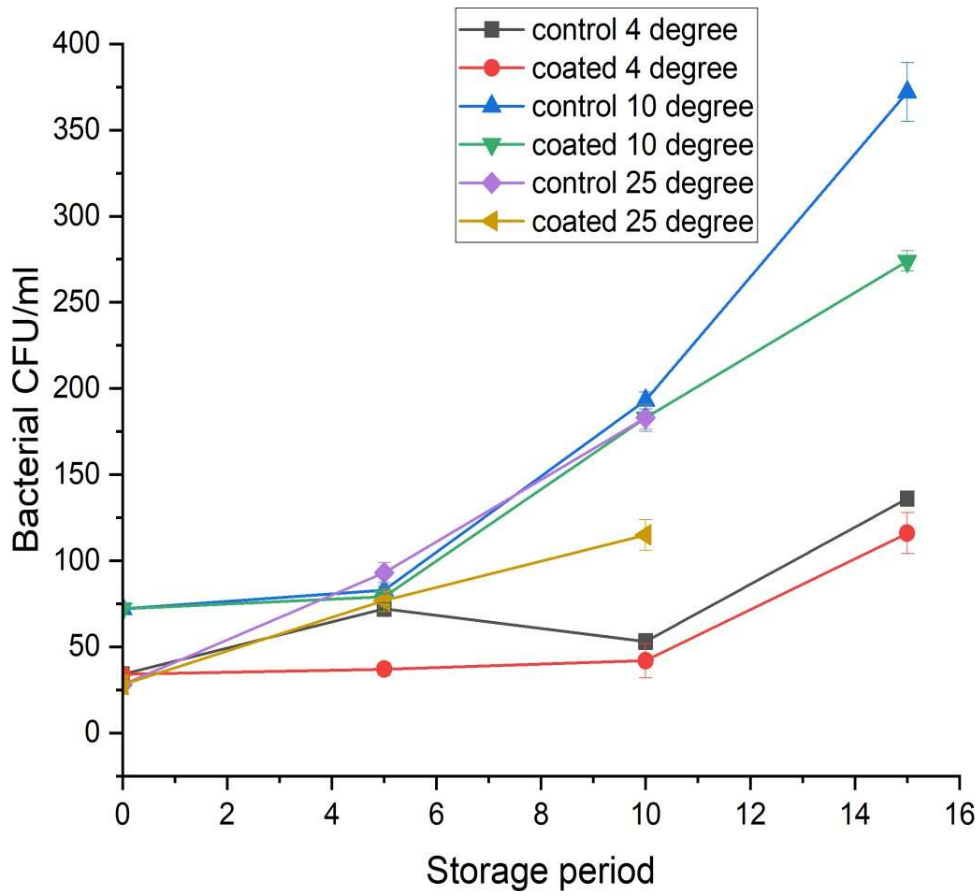


Fig 4.17 (a) Graphical representation of bacterial CFU/ml for coated and control samples stored at 4°C, 10°C and 25°C.

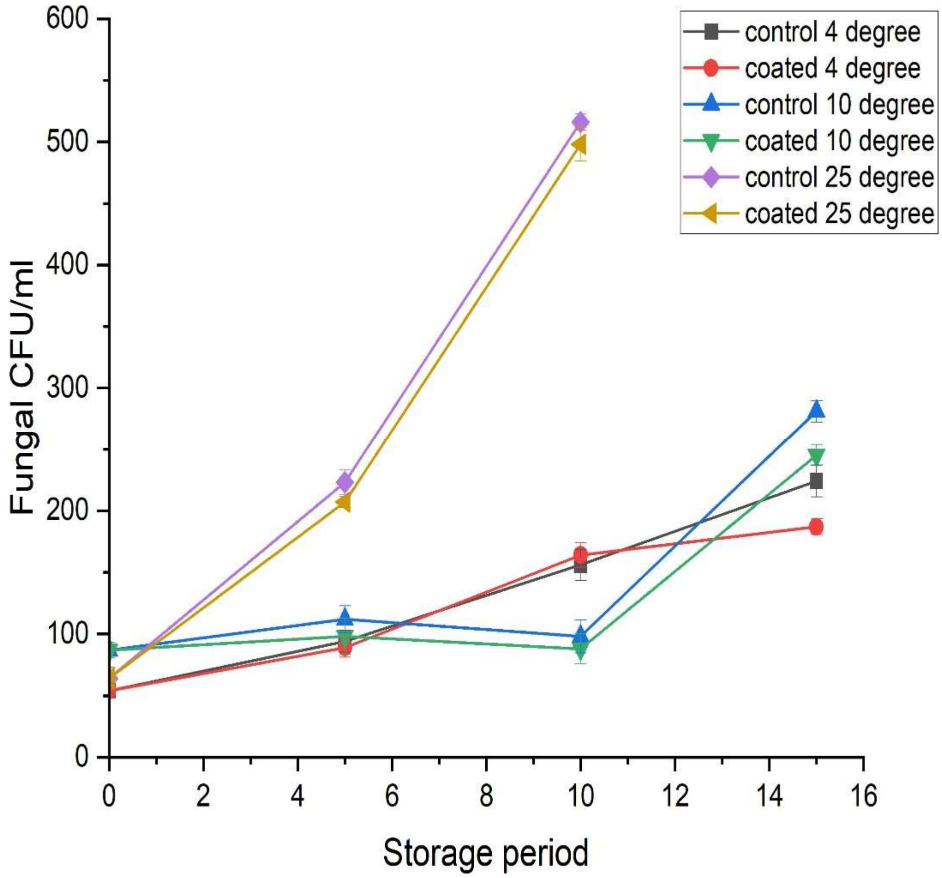


Fig 4.17 (b) Graphical representation of bacterial CFU/ml for coated and control samples stored at 4°C, 10°C and 25°C.

Conclusion

This study investigated the effectiveness of *Moringa Oleifera* plant seed oil and starch extracted from *Syzgium cumini* for developing edible coating for fruits. The outcomes showed that the coating helps to reduce the weight loss of fruits, slowed pH reduction, maintained color intensity and significantly maintains carotenoid content. Quality of papaya was significantly impacted by variations in temperature, with lower temperatures having more beneficial effects. The appearance of papaya was affected by coating, particularly at lower storage temperatures. The ℃was also observed in non-coated samples. Overall, the study shows that the moringa oil-Starch coating could help keep papayas fresher for longer period of time after harvesting by increasing their quality characteristics like weight, color, Carotenoid content, acidity and total soluble content and prolonging their shelf life at different temperature ranges. Moringa oil and starch are a promising safe, easy-to-use, and environmentally responsible way to replace the preservatives and packaging materials that are used to kept fruits fresh. This study confirms the use of natural and edible coating materials for other fruits and vegetables to keep them fresh and can be used at industrial level. These coating also help to maintain the shelf life of fruits during long journeys transportation. In this study, the microbial analysis was checked for the coated and uncoated samples. The papaya stored at lower temperature showed less microbial contamination than the papayas stored at higher temperature 25℃. Hence, more investigation is required for developing more appropriate edible coating using the food by-product extracts like moringa seed oil and starch, which can show better results against the microbial contamination caused to post-harvested fruits at 10℃ or temperature higher than it. At 10℃, samples showed spoilage after the 5 days of storage. In order to keep fruits safe from microbial contamination more comprehensive study and investigation is required.

References

Adjouman, Y. D., Nindjin, C., Kouassi, K. N., Tetchi, F. A., Amani, G. G., & Sindic, M. (2018). Effect of Edible Coating based on improved Cassava Starch on Post-Harvest quality of fresh Tomatoes (solanum lycopersicum l.). *International Journal of Nutritional Science and Food Technology*, *4*, 1–10.

Al-Dairi, M., Pathare, P. B., Al-Yahyai, R., & Al-Mahdouri, A. (2023). Effect on physiological properties of banana fruit based on pendulum impact test and storage.

Al-Rashdi, S., Al-Subhi, N., Al-Dairi, M., & Pathare, P. B. (2024). Effect of A Moringa Oil–Beeswax Edible Coating on the Shelf-Life and Quality of Fresh Cucumber. *Processes*, *12*(6).

Athmaselvi, K. A., Sumitha, P., & Revathy, B. (2013). Development of Aloe vera based edible coating for tomato. *International Agrophysics*, *27*(4), 369–375.

do Nascimento, A., Toneto, L. C., Lepaus, B. M., Valiati, B. S., Faria-Silva, L., & de São José, J. F. B. (2023). Effect of Edible Coatings of Cassava Starch Incorporated with Clove and Cinnamon Essential Oils on the Shelf Life of Papaya. *Membranes*, *13*(9).

López-Díaz, A. S., Antonio-Gutiérrez, O., Palou, E., Mani-López, E., López-Malo, A., & Ramírez-Corona, N. (2025). Post-harvest quality preservation of red globe grapes using grape juice-based edible coatings combined with UVC treatment. *Food Chemistry*, *470*.

Raju, M., Mondal, R., Valliath, A. S., Tejaswi, S., & Das, P. (2023). Enhancement of quality parameters and shelf-life of papaya fruit (Carica papaya L.) by edible coating during storage and transportation. *Plant Science Today*, *10*.

Sharma, M., Bains, A., Dhull, S. B., Chawla, P., Goksen, G., & Ali, N. (2024). Extraction, characterization, and utilization of mung bean starch as an edible coating material for papaya fruit shelf-life enhancement. *Food Science and Nutrition*, *12*(7), 5188–5200.

Zamora, M. C., & Chirife, J. (2006). Determination of water activity change due to crystallization in honeys from Argentina. *Food Control*, *17*(1), 59–64.

Castricini, A., Coneglian, R. C. C., & Deliza, R. (2012a). Revestimento de mamão papaia por películas de amido: Efeito nas características sensoriais. *Ciencia e Tecnologia de Alimentos*, *32*(1), 84–92.

El-Moniem, E. A. A. A., Abdel-Hak, R. S., Yousef, A. R. M., Saleh, M. M. S., & El-Lethy, S. R. (2023). Storability and Fruit Properties of Hass Avocado as Affected by Moringa Seed Oil, Algae Extract and Arabic Gum Postharvest Treatments.

Chemistry, *66*(1), 155–168. Essa, M. Mohamed., Manickavasagan, A.., & Sukumar, E.. (2012). *Natural products and their active compounds on disease prevention*. Nova Science Publishers.

Evans, E. A., & Ballen, F. H. (n.d.). *An Overview of Global Papaya Production, Trade, and Consumption 1.*

Hakim, R. J., Nugrahani, R. A., & Fithriyah, N. H. (2020). Performance of Lecithin Isolate from Vegetable Oil as an Emulsifier on the Beeswax Coating Characteristics.

Hasan, K., Islam, R., Hasan, M., Sarker, S. H., & Biswas, M. H. (2022). Effect of Alginate Edible Coatings Enriched with Black Cumin Extract for Improving Postharvest Quality Characteristics of Guava (Psidium guajava L.) Fruit. *Food and Bioprocess Technology*, *15*(9), 2050–2064.

Oyom, W., Xu, H., Liu, Z., Long, H., Li, Y., Zhang, Z., Bi, Y., Tahergorabi, R., & Prusky, D. (2022). Effects of modified sweet potato starch edible coating incorporated with cumin essential oil on storage quality of ‘early crisp.’ *LWT*, *153*.

Raju, M., Mondal, R., Valliath, A. S., Tejaswi, S., & Das, P. (2023). Enhancement of quality parameters and shelf-life of papaya fruit (Carica papaya L.) by edible coating during storage and transportation. *Plant Science Today*, *10*.

Sharma, M., Bains, A., Dhull, S. B., Chawla, P., Goksen, G., & Ali, N. (2024). Extraction, characterization, and utilization of mung bean starch as an edible coating material for papaya fruit shelf-life enhancement. *Food Science and Nutrition*, *12*(7), 5188–5200.

Solihat, I., Redjeki Setyawati, S., Sulistiawaty, L., & Fadhil Khoirurrizal, M. (2023). SYNTHESIS AND CHARACTERIZATION OF NANO CHITOSAN-AVOCADO SEED STARCH AS EDIBLE FILMS. In *Jurnal Kimia Riset* (Vol. 8, Issue 1).